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COMPUTATIONAL TECHNIQUES FOR DESIGN OPTIMIZATION OF THERMAL PROTECTION SYSTEMS FOR THE SPACE SHUTTLE VEHICLE

VOLUME II ✦ USER'S MANUAL

GENERAL DYNAMICS
Convair Aerospace Division

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FOREWORD

This investigation was performed for the NASA Manned Spacecraft Center Structures and Mechanics Division. Dr. Donald M.Curry was the technical monitor, and Dr. Kenton D. Whitehead was the project manager. The study was conducted by Dr. Whitehead and a project team consisting of Dr. K. T. Shih - Thermodynamics, Mr. G. L. Getline - Dynamics, Mr. R. S. Wilson - Stress, and Messrs R. H. Trelease and S. T. Hitchcock - Weights/Cost Analysis. All work was done at the San Diego Operation of the Convair Aerospace Division of General Dynamics with the exception of consultation provided by Mr. J. D. Anderson of the Fort Worth Operation on the acoustic fatigue computer program. Results of the study are published in two volumes; the Final Report (Vol I) and User's Manual (Vol II).

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SUMMARY

A study was performed to assimilate and develop computational techniques for the design optimization of thermal protection systems for the space shuttle vehicle. The resulting computer program was then used to perform initial optimization and sensitivity studies on a typical thermal protection system (TPS) to demonstrate its application to the space shuttle TPS design. The program was developed in Fortran IV for Convair Aerospace's CDC 6400, but it was subsequently converted to the Fortran V language to be used on the MSC Univac 1108. Documentation for the study is reported in two volumes - the Final Report and the User's Manual. The latter contains input instructions and a sample problem to illustrate use of the program.

The major effort of the investigation consisted of the development of the computational techniques and programming of the subsequent methodology. The program itself was effected in modular fashion to allow continuing improvement and update of the performance prediction techniques. The program logic involves subroutines which handle the following basic functions: (1) a driver which calls for input, output, and communication between program and user and between the subroutines themselves, (2) a thermodynamic analysis which includes prediction of both the aerodynamic heating rates and the resulting heat transfer and temperature response of the TPS, (3) a thermal stress analysis which predicts the internal stresses and creep rates of the TPS by a discrete element analysis which structurally models the TPS subject to both external forces due to aerodynamic pressure and thermal stresses caused by heating, (4) an acoustic fatigue analysis which predicts both the noise excitation due to a number of external sources and the fatigue life of the panel, and (5) a weights/cost analysis which determines the weight and manufacturing cost of the system by identifying and evaluating these parameters for each of the TPS's components parts. In addition, a system total cost is predicted based on system weight and historical cost data of similar systems. Each of the major components of the program described above is complemented by other subroutines which provide specialized calculations for the analyses.

Two basic types of input are provided, both of which are based on trajectory data. In the first, vehicle attitude (altitude, velocity, and angles of attack and sideslip) is input and external heat and pressure loads are calculated. In the second, heating rates and pressure loads are provided to the program as a function of time. Standard program output includes heating rates, temperature, and stresses for the discrete elements of the TPS analyzed as well as dynamic stresses and the number of stress reversals for the panel and its weight and cost. A panel redesign technique is included to increase the panel thickness to transfer mechanical loads and to increase insulation thickness to protect the underlying load-bearing structure. In a subsequent investigation these redesign iterations are being refined.

Optimization and sensitivity studies are performed by the user by varying panel size, material properties, and configuration (six different metallic panel cross-section geometries are provided) in a series of computer runs. The program sizes panel and insulation thicknesses. An optimum design is then identified as the one giving either minimum weight or cost as a function of the parameters being varied for the investigation. Sensitivity studies are performed by noting the change in system weight or cost due to the variation in some independent variable such as trajectory or heating prediction method for an optimum panel configuration.

As the final task of this study, recommendations are made for computer program improvements which include new thermal protection systems (both active and passive) and improved computational and iterative techniques.

SECTION 1

INTRODUCTION

This manual describes the computer program P5490 developed for use in optimizing the design of the thermal protection system for manned spacecraft in terms of weight and cost. A brief description is given of the capabilities and limitations of the program followed by operation instructions and a sample problem. Source listings, descriptive paragraphs of all subroutines, and a flow chart of the program are given in the appendices.

The program starts by calling subroutine INPUT1 to read in data necessary to perform the thermal protection system (TPS) sizing. For a given trajectory, location on the spacecraft, and computational time interval, the subroutine THERMO computes the local pressure and aerodynamic heating rate. The temperature and stress response of the structure are then evaluated by the subroutines CONDTN and STRESS respectively. Panel and insulation thickness are sized by comparing the computed results to thermal and stress constraints. Once the TPS has been sized thermodynamically and structurally, the acoustic fatigue analysis subroutine FATIG computes the dynamic response of the TPS and compares it to the lifetime requirements of the vehicle. Finally, the weight/cost analysis subroutine DRVTPS predicts TPS unit weight and cost.

The program was developed simultaneously in Fortran IV for the CDC 6400 and in Fortran V for the Univac 1108 by the Convair Aerospace Division of General Dynamics.

SECTION 2

PROGRAM CAPABILITIES AND LIMITATIONS

The program has been written in modular fashion. The primary purpose of this is to provide ease of modification. A continual improvement of the program to maintain the state-of-the-art is being conducted under Contract NAS9-11992. The following subsections describe the capabilities and limitations of the program.

2.1 COORDINATE SYSTEMS

In this program, a rectangular coordinate system was adopted. The plane of symmetry of the spacecraft (the pitch plane) is specified as the xz-plane of the coordinate system (Figure 2-1). The location on the spacecraft is described in the program by the distance from the leading edge (or diameter of the body in the case of high angle of attack), and the direction cosines of outer normal from the surface, a unit vector $\bar{n}$

$$\bar{n} = iDnx + jDny + kDnz \qquad (2.1)$$

If the freestream unit velocity vector, $\bar{v}$, is defined as

$$\bar{v} = \frac{\bar{V}}{V} = i\cos\alpha\cos\beta + j\sin\beta + k\sin\alpha\cos\beta \qquad (2.2)$$

where α is the angle of attack and β is the yaw angle, the effective angle of attack, α_{eff}, is then

$$\sin\alpha_{eff} = \bar{n} \cdot \bar{v} \qquad (2.3)$$

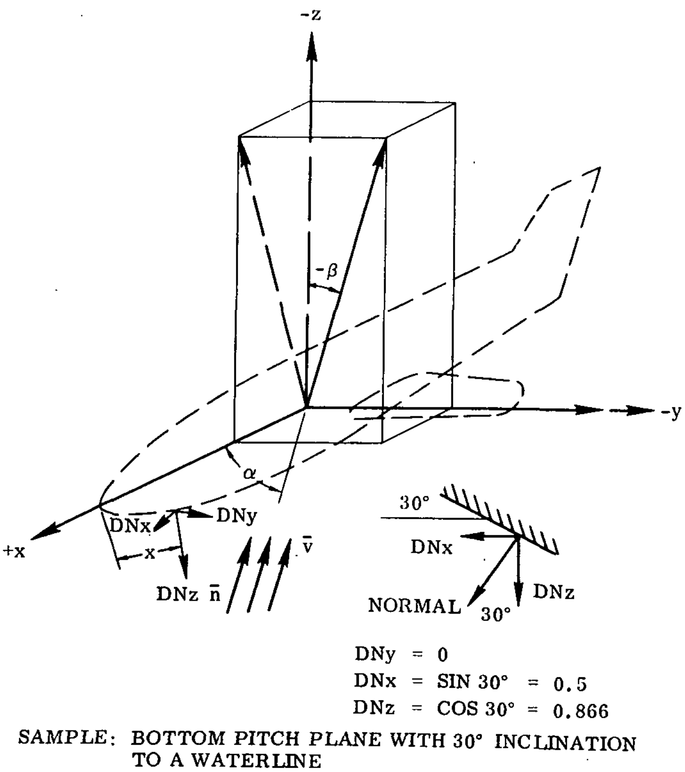

Figure 2-1. Coordinate System

2.2 AERODYNAMIC HEATING

Three methods are employed to specify the aerothermodynamic environment of the local TPS of interest. The first is to input the vehicle trajectory as a function of time (i.e., altitude, velocity, angle of attack, yaw angle). These points are tabulated data, and

the trajectory at a specific time is established by linear interpolation. Freestream properties of temperature, pressure, density, speed of sound, and viscosity are determined from the 1963 Patrick AFB Atmosphere (subroutine PRA63). The second technique is to input the local pressure and heat transfer rate (either steady state or as a function of time). The third technique is simply a statement of the temperature of the first row of segments.

Prediction of aeroheating (subroutine THERMO) can be conventiently classified into two regimes: high and low local angle of attack. For low angle-of-attack applications, the shock waves are assumed attached to the body, and flow field properties can be computed from tangent wedge/cone techniques. Using these local properties, the algorithm then computes local heating rates using either the Eckert reference enthalpy method or the Spalding-Chi technique. Transitional heating between the laminar and turbulent boundary layers is calculated as a linear interpolation of turbulent and laminar heating values, the degree of turbulence depending on the turbulent fraction exhibited by the boundary layer with respect to values of Reynolds number for transition onset and end.

At high angles of attack, the flow field cannot be predicted so conveniently as at low angles of attack. Thus, current state of the art techniques recommend aeroheating rate calculation by swept cylinder methods, either laminar or turbulent. At the moment, no transition criterion has been established for the switch from laminar to turbulent swept cylinder heating prediction techniques.

2.3 STRUCTURAL TEMPERATURE RESPONSE

The temperature response of the internal TPS structure is determined by solving an explicit statement of the Fourier heat conduction law. The structural temperature distributions are evaluated by simulating the TPS as a structure of lumped nodes. Nodal densities, specific heats, and other thermodynamic parameters as well as radiative and conductive heat transfer coefficients between nodes then determine the coefficients of the finite difference analog of the Fourier equation.

Property values for heat conduction analysis (density, emissivity, heat capacity, and thermal conductivity) are fed into the program as constants or as functions of temperature. These points are tabulated data, and the properties at a specific temperature are established by linear interpolation.

Structural temperature response is evaluated by either a one- or two-dimensional conduction program with internal radiation. The structure is divided into an arbitrary number (maximum of 9 columns × 9 segments) of nodes (Figure 2-2).

The CONDTN subroutine accommodates simulation of radiation heat exchange between nodes. There are two general expressions available for calculation of radiation heat exchange. The equation

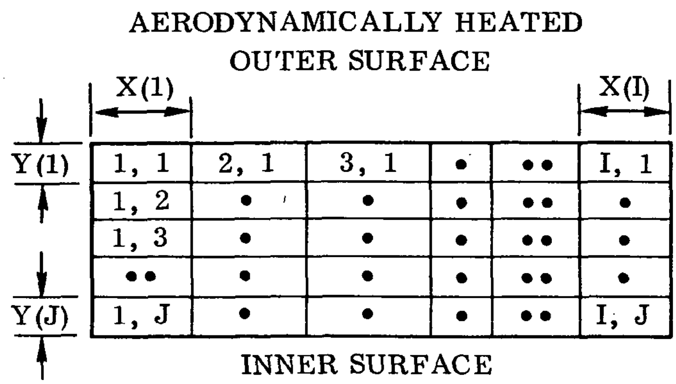

Figure 2-2. Structure Segmentation

$$Q_{ij} = \frac{\epsilon_i \epsilon_j \sigma}{1-(1-\epsilon_i)(1-\epsilon_j)} A_i F_{ij} (T_j^4 - T_i^4) \tag{2.4}$$

describes radiation heat exchange, Q_{ij}, between two parallel plates i and j, where σ is the Boltzmann's constant, ϵ is the emissivity, A is the area, F is the view factor and T is the temperature. Equation 2.4 is an approximate form. For rigorous calculations the "overall interchange factor," $\mathcal{F}_{ij}$ should be computed and supplied as part of the problem input. By substituting $\epsilon_i = \epsilon_j = 1$ and $F_{ij} = \mathcal{F}_{ij}$ into equation (2.4) we have

$$Q_{ij} = \sigma A_i \mathcal{F}_{ij} (T_j^4 - T_i^4) \tag{2.5}$$

2.4 STRESS ANALYSIS

The stress analysis (subroutine STRESS) is performed for any of six simply-supported panels (Figures 2-3 and 2-4) with joints which permit free thermal expansion. Figure 2-3 gives overall geometrical dimensions for the panel, and geometries for individual panel configurations are given in Figure 2-4. The loadings considered are bending due to aerodynamic pressure and the internal forces induced by temperature gradients within the panel cross section.

The panels are segmented for thermal stress analysis; Figure 2-5 shows the panel segmentations together with the conduction matrices. It is essential that the conduction input obeys the matrix given in this figure.

The following property values of panel material are needed for stress analysis; they are input as tabulated data.

a. Young's modulus vs. temperature.

b. Coefficient of thermal expansion vs. temperature.

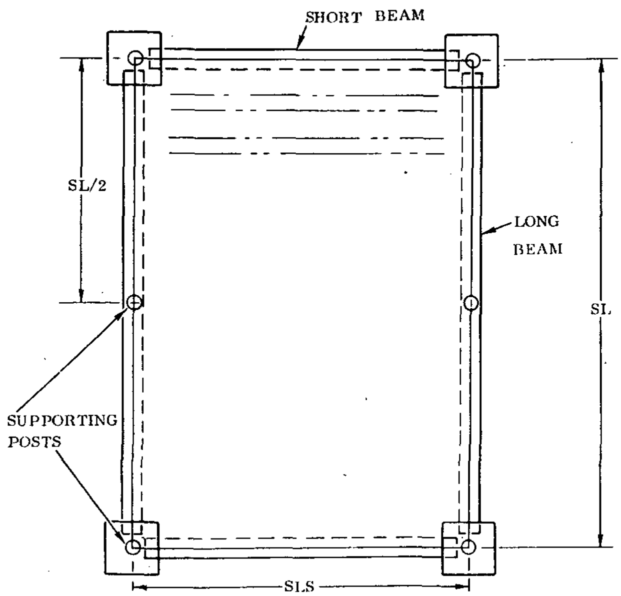

Figure 2-3. Panel Overall Geometry

c. Yield strength vs. temperature.

d. Ultimate tensile strength vs. temperature.

e. Larson-Miller parameter for strain 1 vs. stress.

f. Larson-Miller parameter for strain 2 vs. stress.

2.5 ACOUSTIC FATIGUE

The acoustic fatigue analysis (subroutine FATIG) computes the fundamental frequency of each of four different panel configurations (Figure 2-6). Although not all of these are in use presently, they will be utilized for concepts under development. Noise computations are performed for each of four different sources (turbulent boundary layer, boost engines, jet flyback engine, or scubbing by the exhaust of the jet flyback engines). Each sound pressure level is a function of local geometry (e.g., the distance between the source and the point of interest for the case of engine induced noise, or the run length distance for the turbulent boundary layer, Figure 2-7. The panel moment of inertia about the cross-section neutral axis is computed external to the program by standard methods of stress analysis (Reference 2). Dynamic stresses are computed for each sound pressure level; these are adjusted to account for a dynamic magnification factor due to resonance and for a local stress raiser due to edge conditions. Critical stress levels for each noise source are determined by equating the randomly applied excitation energy to the allowed levels of stress as a function of number of stress reversals determined by test. (The latter information is calculated external to the program from data of the final report and is input as a third-degree least-squares curve fit of stress in kips per square inch as a function of stress reversals.) The composite critical stress is determined as the square root of the sum of the squares, and the corresponding equivalent number of stress reversals is determined by equating the total energy absorbed by the system at the composite critical stress to the sum of all the energies absorbed by the application of random noises due to each of the four possible noise sources. The resulting critical stress and number of stress reversals are compared to the allowable values to see if they have been exceeded.

2.6 WEIGHT AND COST ANALYSIS

The weights/cost analysis predicts the weight and cost per unit area of three different panel configurations (Figure 2-6) and three different concepts of heat post supports (Figure 2-8). The type of panel and support structure is input to the program along

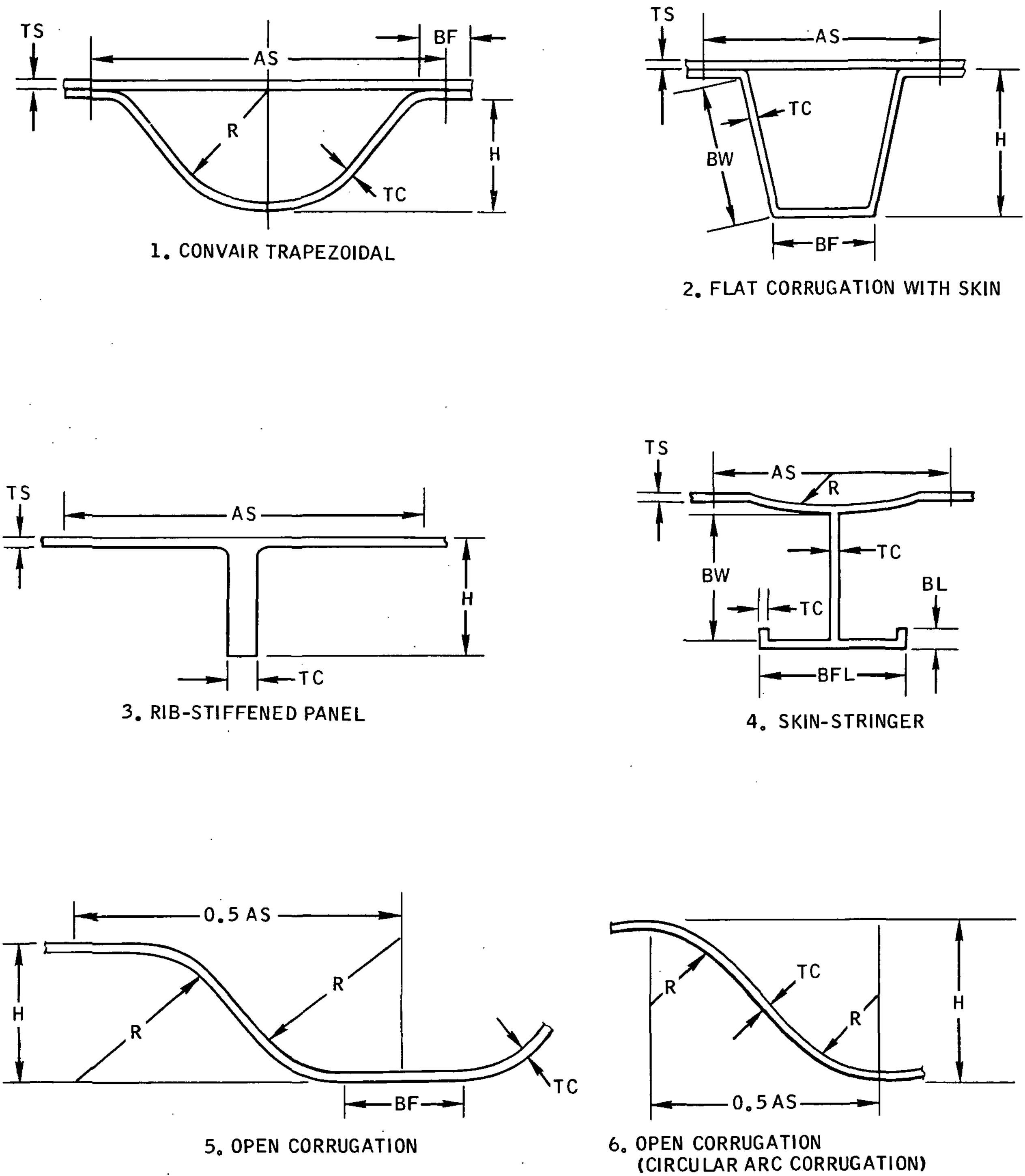

Figure 2-4. Panel Geometries

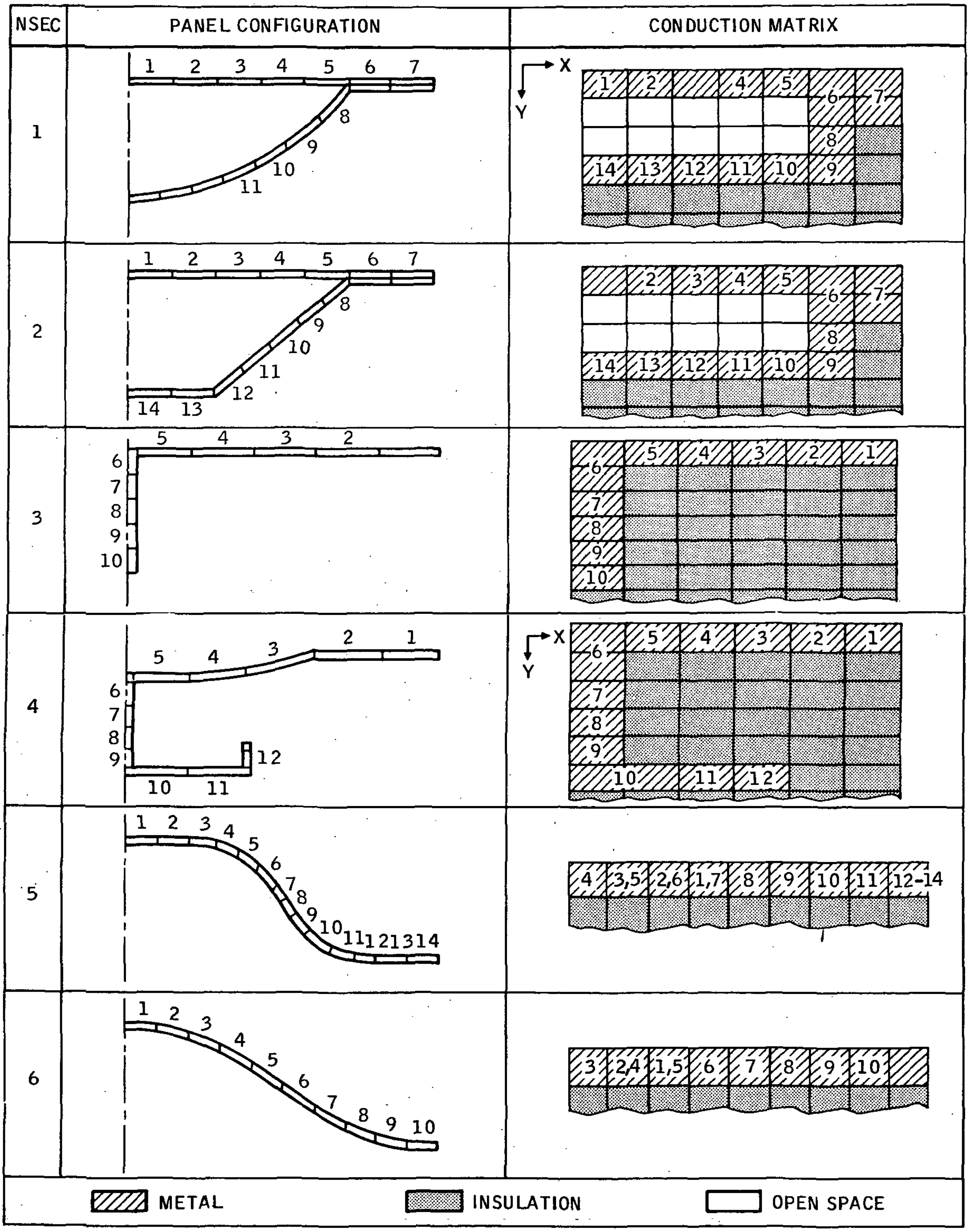

Figure 2-5. Configurations for Stress Analysis

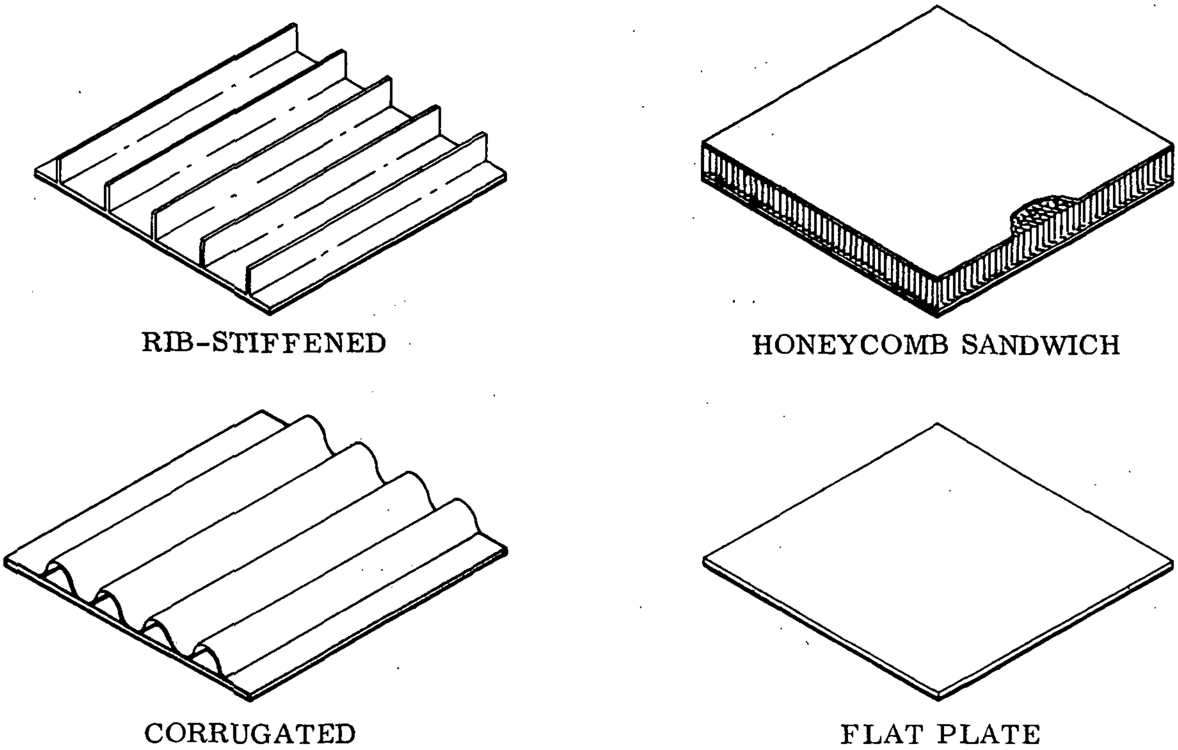

Figure 2-6. Sonic Fatigue Analysis Configurations

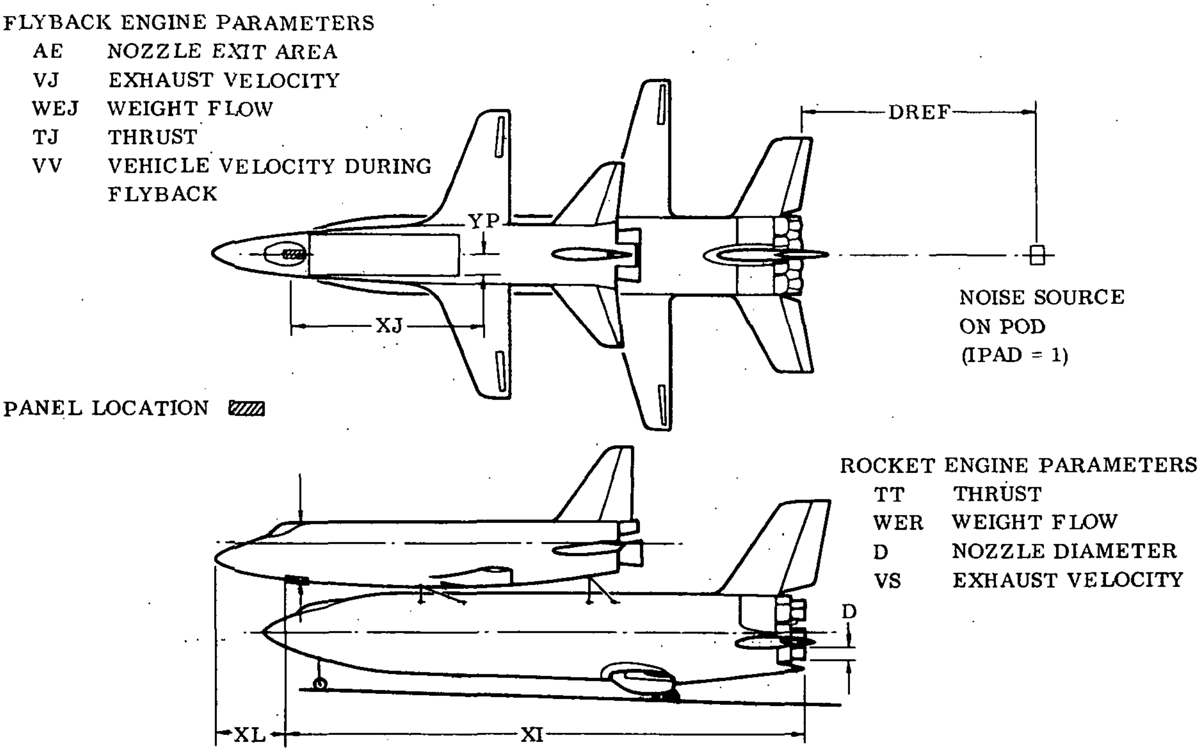

Figure 2-7. Sonic Fatigue Input Nomenclature

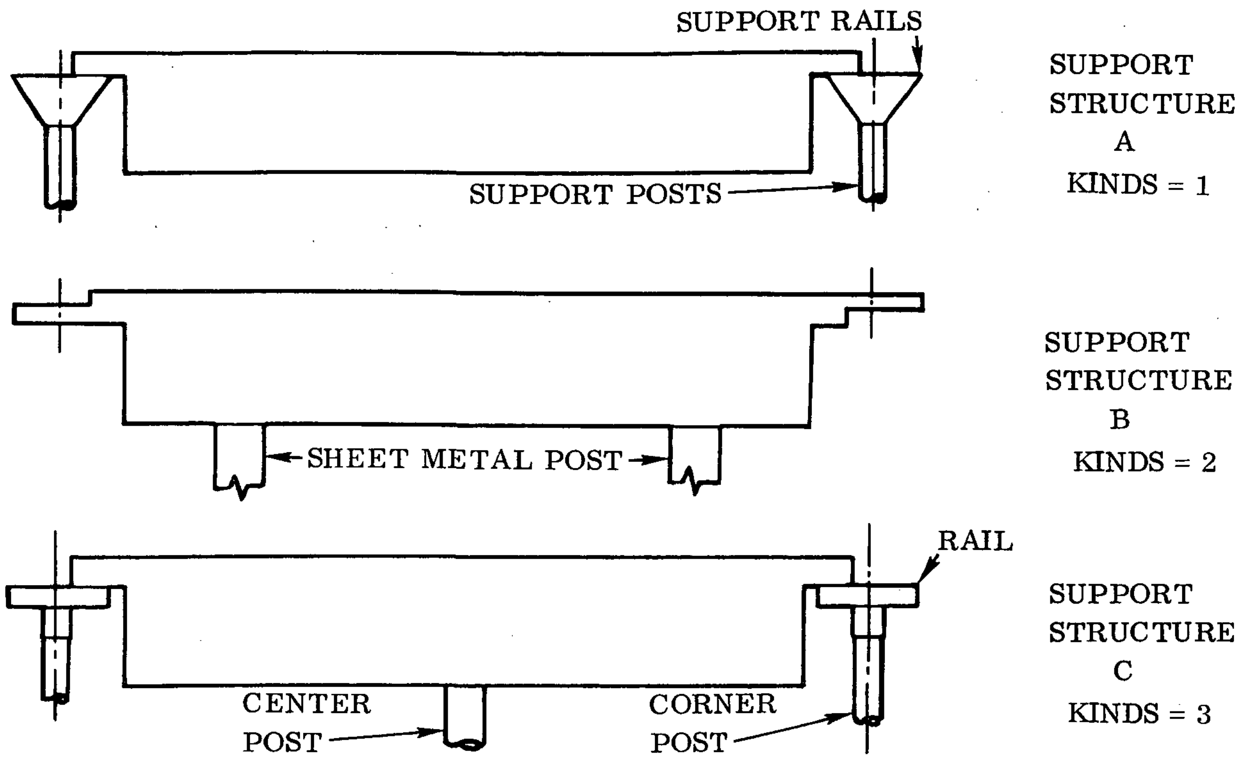

Figure 2-8. Schematic of Supporting Structures

with the panel and supporting structure geometry (Figures 2-9 through 2-13). The total system weight per panel is computed as the summation of weights of the various components, and weight per unit area is determined by dividing panel weight by panel area. Costs per unit area are determined by calculating the material, manufacturing, engineering, and refurbishment costs for each panel configuration and then dividing by panel size. Each individual cost (material, manufacturing, etc.) is calculated by identifying the type of material purchased, the form in which it is purchased, and the operations needed to manufacture the part (clamping, drilling, inspecting, etc.) as well as the manhours required for supporting activities (sustaining engineering, tooling, and the like). At the present time these data are stored within the computer program as tabulated values.

Costs are computed by two different techniques. The first predicts the costs of manufacturing the TPS per unit area and includes materials and manufacturing costs. Since some of the basic cost information stored within the program is still under development, values for the manufacturing costs should be taken under advisement.

The program total cost is based upon techniques generated for the space shuttle booster. The primary driver is weight of the TPS, and all costs are based on an area of 22,000 ft^2 on the vehicle. Hence, unit area costs can be obtained by dividing total program costs by this number. All cost factors are currently embedded in the program, but refinements are being made to include a wider range of materials and configurations as well as to permit the user's input of his own cost information.

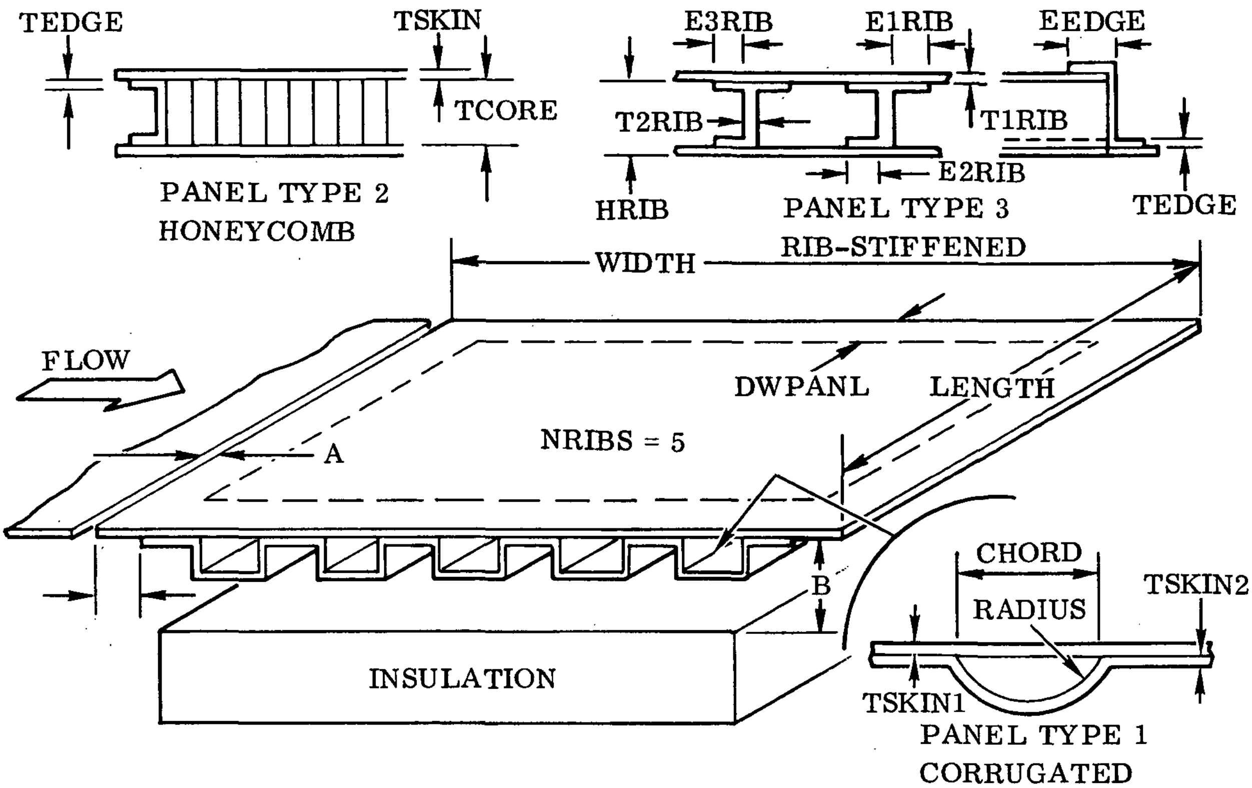

Figure 2-9. Panel Nomenclature for Weights/Cost

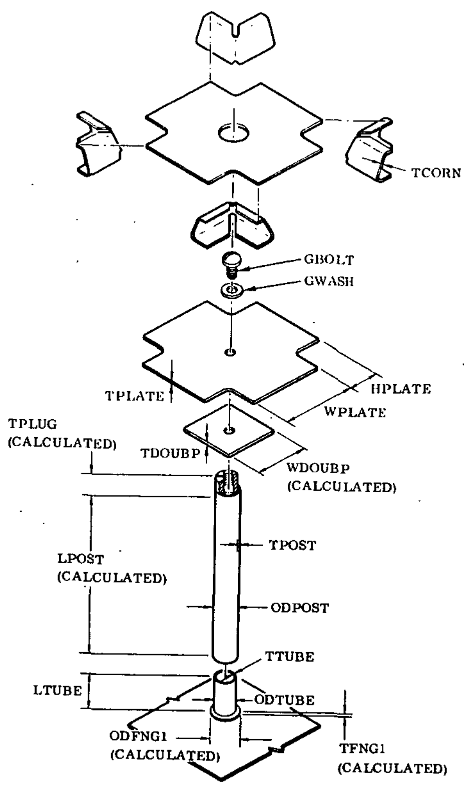

Figure 2-10. Cruciform and Support Post Assembly (Concept A)

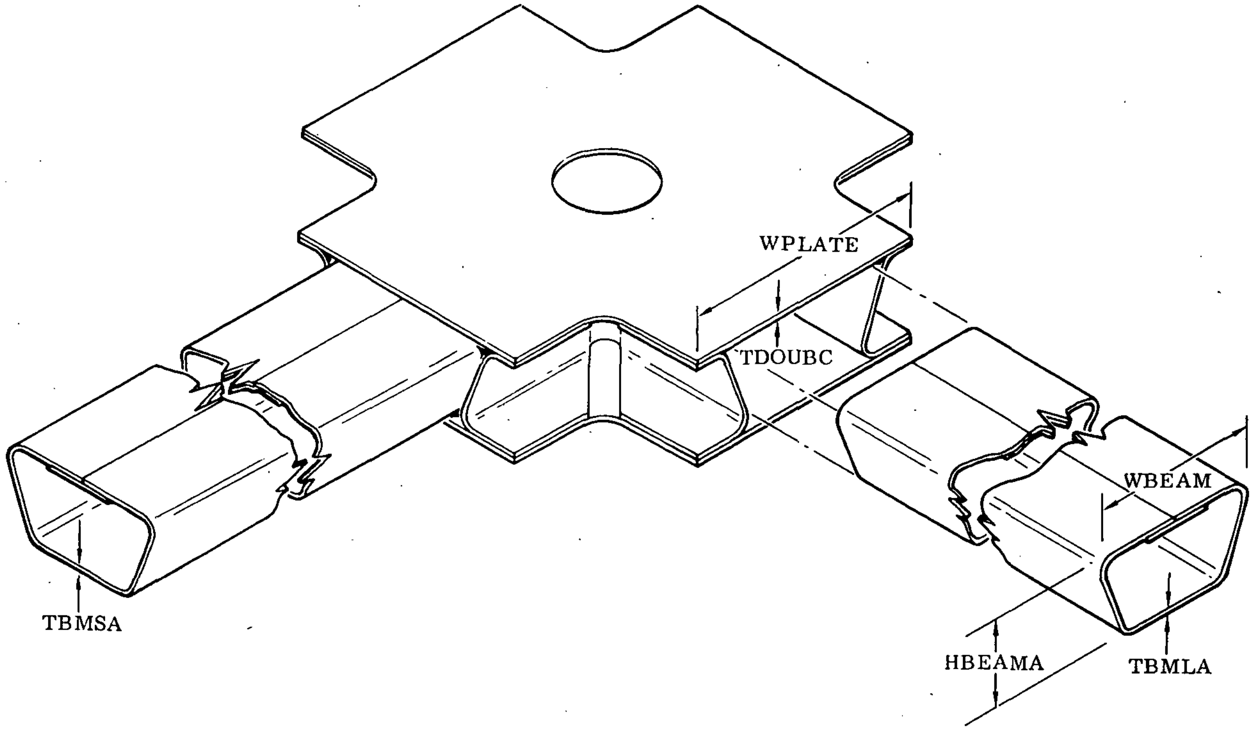

Figure 2-11. Cruciform and Support Beams (Concept A)

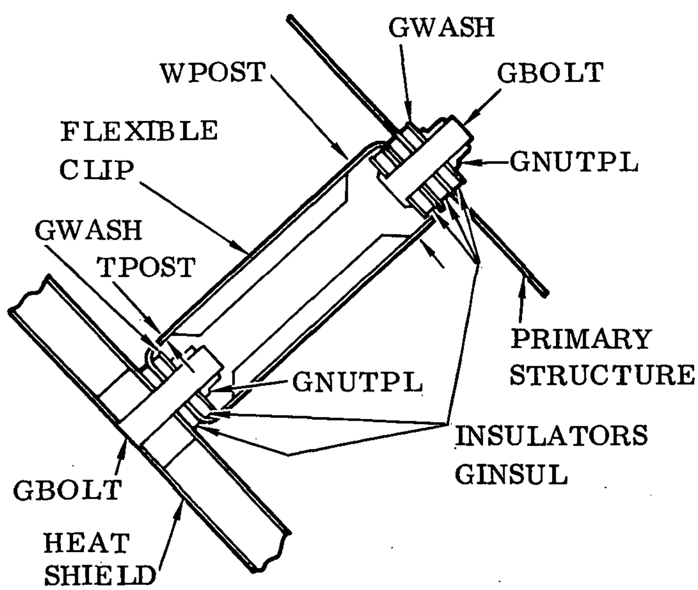

Figure 2-12. Sheet Metal Standoff Post (Concept B)

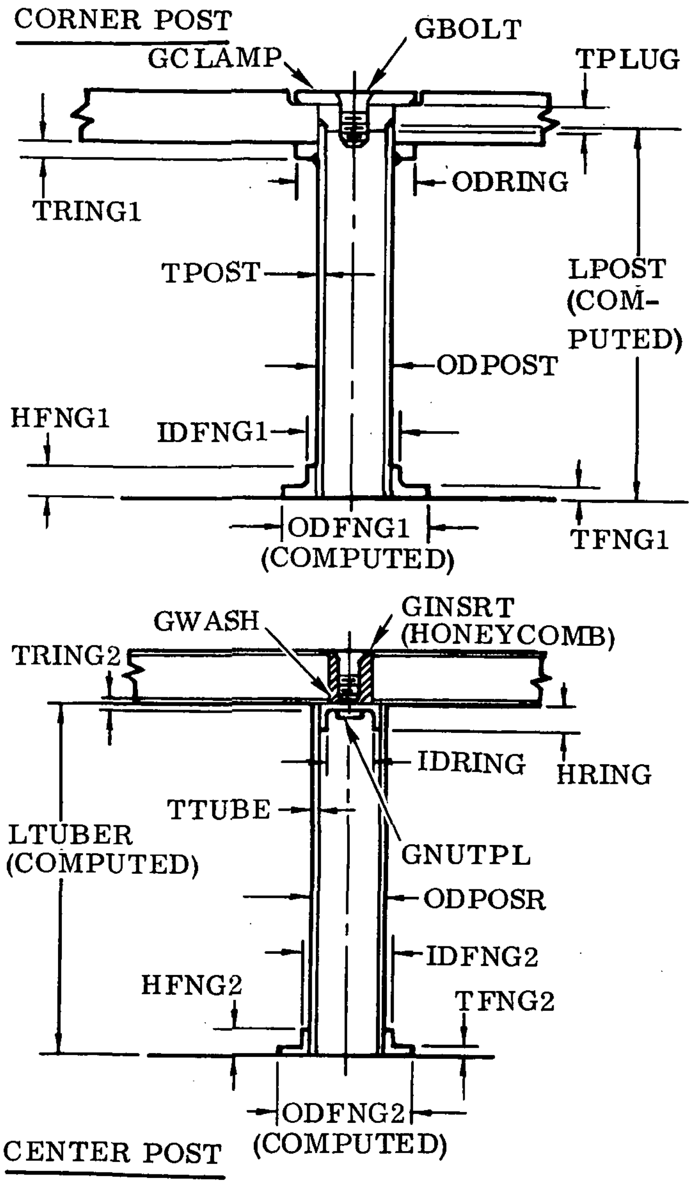

Figure 2-13. Support Post (Concept C)

2.7 TPS SIZING ROUTINE

A short discussion of the TPS sizing routine is included in this manual to facilitate the user's understanding of the mechanics of the procedure. First, it must be remembered that the two parameters varied in the sizing procedure are the panel thickness and the insulation thickness. All other material properties and geometric parameters remain constant. It is recommended that all support structure thicknesses be taken as minimum gauge for the particular material considered.

Thermodynamic constraints to the system are input as maximum allowable temperatures for each material in the parameter TALLW(I) (e.g., an aluminum substructure would be characterized by an allowable temperature of approximately 250°F). The temperature of each material is monitored throughout the flight and compared to the maximum allowable. A word of caution is in order here, however. The program user should be careful that the insulation to be sized lies between the exterior surface (more specifically, the heat source) and the material whose maximum allowable temperature will be the design point (Figure 2-14a). If this is not the case, then when the maximum allowable temperature is exceeded, the insulation thickness will be increased, thus driving the actual temperature of the critical material even higher. Consider as an example the configuration shown in Figure 2-14b. When the tank wall exceeds its maximum allowable temperature, the insulation will be thickened and the tank wall will get hotter. At the moment, there is no logic in the computer code to guard against this occurrence.

When an actual temperature exceeds the maximum allowable, the insulation thickness is increased, the program returns to the starting point of the calculations, and the computations are begun anew. The insulation thickness is continually increased until

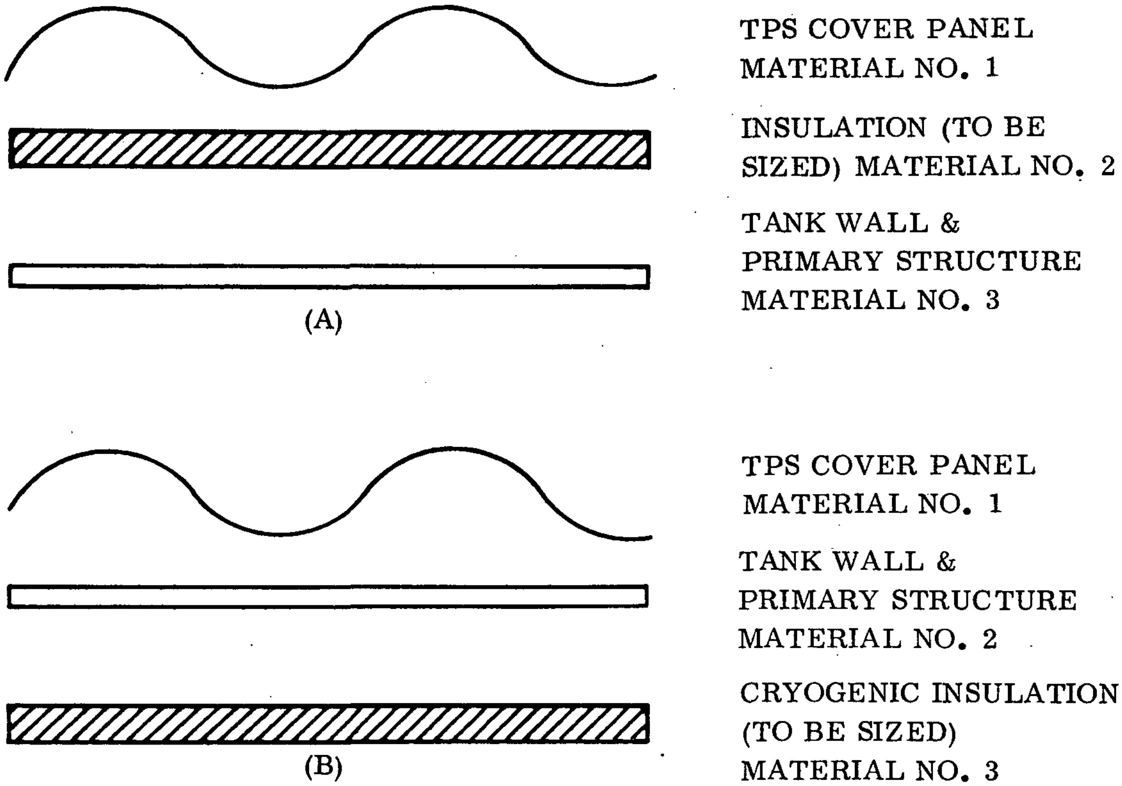

Figure 2-14. Schematic of Insulation Location

either the actual temperature of the critical material is less than the maximum allowable, or until the insulation thickness reaches one foot. For the latter case, the run is terminated. Here, the program user should again be critical of the printed results. This first generation computer program does not decrease the insulation thickness once a value is found which satisfies the temperature constraints. Hence, the insulation thickness may be beyond design requirements, and only perusal of the resulting temperature distribution will determine this fact. A subsequent computer run with a different initial insulation thickness may be necessary. Messages describing all changes in insulation thicknesses and/or termination of the case (along with appropriate temperatures) are printed out.

Structural or stress constraints to the system are not input by the program user but instead are inherent in the design technique. Six different design factors are considered in the stress analysis of the TPS panel. Tests to satisfy these design constraints are made on each of the nodes comprising the discrete element analysis of the various panel configurations (Figure 2-5). Each design factor and an explanation of its use is presented in Table 2-1. All of these factors are ratios of actual stresses or strains to allowable values for the particular material; they are fundamental expressions used in determining margins of safety in any stress analysis.

Table 2-1. Stress Design Factors

Design Factor	Design Point
T1MS	Ultimate Tension
Y2MS	Yield Strength
C3MS	Ultimate Compression
C4MS	Buckling of Corrugation*
F5MS	Crippling of Flange No. 1
F6MS	Crippling of Flange No. 2

*Applicable only to Configurations 1 and 2.

The stress analysis is called during each print interval of the trajectory. This increment is determined by the input parameter DELTA. When the subroutine STRESS is called, the discrete element thermal stress analysis is performed, and the design factors of Table 2-1 are stored for each discrete element of the cross-section. The stress analysis may be performed up to 99 times during the trajectory since this is the amount of storage now called in the program. At the end of the trajectory, the stress analysis subroutine assesses all of the design factors accumulated in the run and identifies the largest ones. If they are all positive and the actual values do not exceed the allowable ones, the analysis is terminated. On the other hand, if a design factor is negative, then the panel thickness is increased to accommodate the applied loads. On the first interation, the skin thickness is increased by 0.010 in. and the stress analysis at the critical time is performed again using the temperature distribution and external forces stored for that particular time of the trajectory. If this new thickness is not sufficient, a Newton-Raphson technique is employed to extrapolate to a new thickness. The procedure continues until a thickness is determined for which all design factors are positive. The sizing of the structure is demonstrated in the sample problem run in Section 4.

There are two limitations to the present program which should be kept in mind by the program user. First, the stress analysis is complete when all design factors are positive. However, no check is made to see how far from zero these factors are. It is possible that panel thickness derived from an extrapolation which was determined from points below a design value may result in a panel thickness that is significantly above design requirements. Second, all thermal stress analyses are performed using the temperature distribution stored in core, i.e., that which corresponds to the panel thickness originally input to the program. Experience has shown, however, that since stresses are dependent on temperature gradients and not absolute values of temperature, the gradients are insensitive to small changes in panel thickness.

SECTION 3

PROGRAM OPERATION INSTRUCTIONS

This section presents the information required for effective use of the program. The instructions for correct program input are given in Section 3.1, a description of the program output is given in Section 3.2, and error statements are shown in Section 3.3.

3.1 INPUT

The input system has been designed to allow multiple cases with the complete input data deck consisting of input packages for each case. The first case generally requires specification of all necessary parameters whereas, in subsequent cases, a namelist DATANU can be used to make changes of parameters. A complete input package is composed of 30 records; a record is simply a convenient gathering of similar terms or groups of terms. The input symbols are defined in Table 3-1, and the format records are given in Table 3-2 and illustrated in Figure 3-1.

The formats of data input are of the form nEw.o. Thus, a decimal point may appear anywhere in the field. However, if the exponential notation E xx is used, it must be right-hand justified. Any field may be left blank. The blank is interpreted as a 0 (integer) or 0.0 (floating point).

Simplification has been made in the input subroutine to allow changing the input parameters by employing a namelist DATANU. This method is implemented when the parameter JI=2 (Record 1, Figure 3-1). In addition, two parameters NUDIM and NUTRAJ can be used to further simplify the input. If the parameter NUDIM=1, the program reads records 13 through 18. If NUTRAJ=1, the program reads the first trajectory card (this option may be used together with NANG=2). If NUTRAJ=2, the program looks for a new set of trajectory data. The definitions of the input symbols remain as given in Table 3-1. The namelist input starts with $ in column 2 followed immediately by the name DATANU with no embedded blanks. Succeeding are data items and a $ at the end. A sample of DATANU input is illustrated in Figure 3-2.

Data for the weights and cost analyses are also read in using conventional formats, but they are read into the subroutine DRVTPS. Results of this analysis are output from this portion of the program also. The weights/cost input variables are indicated also in Table 3-1 starting with record 27.

3.2 OUTPUT

The program output consists of three distinct sections. They are illustrated in Section 4. The first includes the case identification and printout of the input data. The last

line of print is the phrase END OF INPUT. This section of the output is accomplished by the subroutine INPUT1.

The second section of the output consists of results. Numerical values are printed on the line below each heading. Output symbols are defined in Table 3-3.

The third section of the output is the debug results output. This section presents the values of parameters which are not normally required but which may be helpful in tracking down the source of errors. This is especially helpful when a new subroutine is added or an existing subroutine is modified. The debug output is not printed unless it is specially requested by means of input a 1 of NPRT in the input data.

3.3 ERROR STATEMENTS

a. ALTITUDE LT 0 OR GT 700000 FT — Trajectory corresponds to an altitude out of range of PRA63 subroutine.

b. LOCAL VELOCITY SQUARE IS NEGATIVE — This comment is printed when a calculated local velocity square becomes negative in subroutine THERMO.

c. ERROR IN OBSPL COMPUTATION — Function Curve F out of range.

d. SEGMENT NUMBER IJ TEMPERATURE CHANGE IS GREATER THAN 500 DEG — Conduction solution is unstable; however, the program normally readjusts the computation true interval. The computation will be stopped for a readjusted true interval less than 0.1 sec (subroutine CONDTN).

e. NO. OF TITLE CARD IS GREATER THAN 10 — Subroutine INPUT1 limits title cards to 10.

f. NO. OF TRAJECTORY IS GREATER THAN 99 — Subroutine INPUT1 limits trajectory cards to 99.

g. OX ARGUMENT ERROR IN TABLE — Error in Function Table.

Table 3-1. Input Symbols

Record	Variable Type	Symbol	Definition
1	Alphanumeric	TITLE	Case identification and comments, maximum 10 cards
1	Integer	JI	Indicator marking the last title card which specifies the input data form, input a 1, 2 or 3 1. Use standard input formats 2. Use the namelist DATANU (see Figure 3-2) 3. Same as 1 but do not read trajectory cards
2	Integer	ICONF	Specifies body configuration, input a 1, 2 or 3 1. Flat plate, wedge or cylinder 2. Cone 3. Sphere
		IQCON	Specifies variation of input heat transfer multipliers, laminar and turbulent input a 1, 2, or 3 1. QCONL (I) = QCONT(I) = 1 (no input required) 2. Input QCONL(I). QCONT(I) = QCONL(I) 3. Input both QCONL(I) and QCONT(I)
		IQINP	Specifies variation of trajectory cards, input a 1, 2 or 3 1. Input trajectory 2. Input local heat flux and pressure 3. Input temperature of the 1st row segments and local pressure
		ITURB	Specifies turbulent prediction method, input a 1 or 2 1. Eckert reference enthalpy 2. Spalding-Chi
		IWALT	Specifies conditions of wall temperature, input a 1 or 2 1. Uniform 2. Nonuniform

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
		NANG	Specified variation of input angle of attack, input a 1 or 2 1. α , β are function of trajectory 2. α = ALPHA(1), β = BETA(1)
		NCOLM	Number of Columns ≤ 9 1. One-dimensional heat conduction 2. Two-dimensional heat conduction
		NSEG	Number of segments ≤ 9
		NMAT	Number of materials ≤ 9
		NRSG	One-dimensional case (NCOLM=1) number of internal radiation gaps Two-dimensional case (NCOLM>1) number of internal radiation segments, for segments which have more than one face radiation interchange, count each face as one segment ≤ 18
		NCRC	Specifies coordinate systems used for conduction analysis, input a 1 or 2 1. Rectangular coordinate 2. Cylindrical coordinate Use only 1 for this version
		NSECT	Panel configurations (see Figure 2-4) input a 1, 2, 3, 4, 5 or 6 1. Convair trapezodial 2. Flat corrugation with skin 3. Rib stiffened panel 4. Skin stringer 5. Open corrugation 6. Circular arc corrugation

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
		NINS	Specifies input material number of the insulation (limited to one material) to be sized. If insulation sizing option is not used, leave blank.
		NF	Number of flights.
		NPRT	Specifies output form, input a 1 if "long" print out option is used. Leave blank for "short" print out
3	Real	DNX	Direction cosines of outer normal from surface
		DNY	(See Figure 2-1)
		DNZ	
		XDST	Distance from the leading edge, ft
		DIAM	Diameter of a sphere or cylinder, ft
		AROD	Ratio of shoulder radius to body diameter
		XEMIS	Outer surface emissivity
		FACC	Factor to increase insulation thickness
4	Real	STAAT	Time to start computation, sec
		DELTA	Computation interval, sec
		WROTE	Print interval, sec
		STOOP	Time to stop computation, sec
5	Real	AS	Pitch of corrugations or ribs, in. (See Figure 2-4)
		R	Radius of corrugations, in. (See Figure 2-4)
		HH	Depth of section, in. (See Figure 2-4)
		TS	Skin thickness, in. (See Figure 2-4)

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
		TC	Corrugation thickness, in. (See Figure 2-4)
		SL	Overall width of panel, in. (See Figure 2-3)
		SLS	Overall length of panel, in. (See Figure 2-3)
		BE	Distance of reaction from panel edge, in. (See Figure 2-4)
6	Real	F07	Secant yield stress $F_{0.7}$ (Ramberg- Osgood) lb/in^2. (Ref. 3)
		UF	Ultimate factor
		DST	Difference between two values of creep strain used for Lawson-Miller data in./in.
		EALL	Allowable creep strain in./in.
		CRN	Shape parameter for stress strain curve (Ramberg-Osgood) (Ref. 3)
		BF	Width of flange or flat segment (Conf. 2) in. (See Figure 2-4)
		BFL	Width of inner flange (Conf. 4) in. (See Figure 2-4)
		BL	Width of lip on inner flange (Conf. 4) in. (See Figure 2-4)
7	Real	TALLW(I)	Allowable temperature of the material, R°
8	Real	EMIS(I)	Emissivity of the material
9	Real	RHO(I)	Density of the material, lb/ft^3
10	Integer	ID (I, J)	Specifies input of material property tables input a 1 or 2 or leave blank to skip input

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
10	Integer	ID(I, J)	(Cont'd)
			1. Read AY only (AX same as before)
			2. Read both AX and AY
10	Integer	MPT(I, J)	Number of pairs or points
11	Real	AX(I, J, K)	Independent variable
12	Real	AY(I, J, K)	Dependent variable
			I = 1, 2, ..., NMAT
			J = 1. Thermal conductivity
			2. Heat capacity
			3. Young's modulus
			4. Coefficient of thermal expansion
			5. Yield strength
			6. Ultimate tensile strength
			7. Larson Miller parameter for strain 1
			8. Larson Miller parameter for strain 2
			K = 1, 2 ..., MPT(I, J)
13	Real	X(I)	Width of the Ith Column, ft
14	Real	QCONL(I)	Laminar heat transfer multiplier of the Ith column, omit if IQCON=1 or NCOLM=1
15	Real	QCONT(I)	Turbulent heat transfer multiplier for the Ith column, omit if IQCON$\neq$3 or NCOLM=1
16	Real	Y(J)	Thickness of the Jth segment, ft
17	Integer	MAT(I, J)	Specifies materials of column I, segment J
			A zero denotes a void.

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
			1-9, material number negative. The segment will be grouped together with the right-hand side segment for condition computations
17	Real	TAMP(I, J)	Specifies initial temperature of column I, segment J, $^{\circ}$R
			Omit record 18 if NCOLM=1 or NRSG=O
18	Integer	NR(N)	Specifies nodes with internal radiation exchange.
			Example: 18 means column 1, segment 8.
			For segments which have more than one side have radiation exchange, treat each side as a segment in the order of left-right-upper-lower.
		NI(N)	Number of nodes to be interacted with node NR(N), ≤ 9
		MR(M, N)	Specifies nodes to interchange with node NR(N)
18	Real	VFACT(M, N)	View factors or $\mathcal{F}_{ij}$ with EMIS(I) = 1
19	Integer	IPFI	Number of noise sources to be considered 1. Turbulent boundary layer 2. Rocket engine 3. Jet engine 4. Jet engine scrubbing
		IPF(I)	Identifies by number the noise sources
		IPAD	Specified if vehicle is on the pad
			Zero - not on pad
			Non-zero - on pad
		KFLEX	Flexural rigidity index
			O ~ if structure symmetrical, rigid
			1 ~ if unsymmetrical and/or flexible
		NPAN	Panel configuration index
			1 ~ flat plate 2 ~ honeycomb sandwich
			3 ~ integrally stiffened 4 ~ corrugated

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
20	Real	DT(1)	Period of turbulent boundary layer noise excitation, sec
		XL	Run length of turbulent boundary layer, feet
		REY	Local Reynolds number
		VU	Local velocity, ft/sec
		QL	Local dynamic pressure, psi
		AMACH	Local Mach number
21	Real	DT(2)	Period of rocket engine noise excitation, sec
		TT	Rocket engine thrust, lb
		WER	Rocket engine weight flow, lb/sec
		D	Rocket nozzle exit diameter, ft
		VS	Rocket exhaust velocity, ft/sec
		XI	Distance between point of interest and rocket engine exit, ft
		DVEH	Vehicle diameter, ft
		YCL	Buttline distance between panel and vehicle centerline, ft
		DREF	Reference distance between noise source on pad and rocket engine exhaust plane, ft
22	Real	DT(3)	Period of jet (flyback) engine noise excitation, sec
		AE	Nozzle exit area, ft
		VJ	Jet velocity, ft/sec
		WEJ	Jet engine weight flow, lb/sec
		VV	Vehicle velocity at flyback cruise, ft/sec
		TJ	Jet engine thrust, lb
		XJ	Axial distance from point of interest to jet engine exit nozzle, ft
		YP	Radial distance from point of interest to jet engine nozzle, ft (less than 200 ft)

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
23	Real	DT(4)	Period of jet (flyback) engine scrubbing noise excitation, sec
24	Real	HPAN	Panel thickness, inches
		HC	Core thickness, inches (for honeycomb sandwich)
		AI	Panel moment of inertia, in.^{4}
		AIY	Panel moment of inertia, in.^{4} (for normal direction of corrugated panel)
		AW	Panel length, ft
		BW	Panel width, ft
		EP	Modulus of elasticity for panel, psi
25	Real	C(I)	Coefficients of a least squares, 3rd order curve fit of allowable S-N data
		RHOP	Panel material density, lb/ft^3
26	Real	TIME(I)	Time in trajectory, sec, I ≤ 99
		ALT(I)	IQINP=1. Altitude, ft 2. Local heat flux, Btu/ft^2-sec°R 3. Temperature of 1st segments °R Note: QCONL(I) may be used to obtain a distribution of Q(I) or TEMP(I, 1)
		VINF(I)	If IQINP=1, free stream velocity, ft/sec If IQINP=2, 3 local pressure psia
		ALPHA(I)	Angle of attack, degrees
		BETA(I)	Yaw angle, degrees
		HINSD(I)	Convection heat transfer coefficient to internal fluid. Btu/ft^2 -sec°R (input 1.E9 to keep last row of segments at the initial temperature)
		TINSD(I)	Bulk temperature of internal fluid, °R
		NREADT	Non-zero indicator marking the last trajectory card

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
27	Integer	KINDP	Specifies panel configuration, input a 1, 2, or 3 1. Corrugated (either open or closed) 2. Integrally stiffened 3. Honeycomb
	Integer	KINDS	Specific supporting structure configuration, input a 1, 2, or 3 1. Configuration type A 2. Configuration type B 3. Configuration type C
	Real	LENGTH	Panel length, in.
	Real	WIDTH	Panel width, in.
	Real	DLPANL	Panel length overlap, in.
	Real	DWPANL	Panel width overlap, in.
	Real	A	Distance between adjacent panels, in.
	Real	B	Airspace gap between panel and insulation, in.
28	Real	PINS1	Density of insulation type 1
	Real	PINS2	Density of insulation type 2
	Real	PINS3	Density of insulation type 3
29[1]	Integer	NRIBS	Number of corrugations across panel width
	Real	CHORD	Corrugation chord length, in.
	Real	RADIUS	Corrugation radius, in.
	Real	PSKIN1	Density of material of skin panel, lb/in.^{3}
	Real	PSKIN2	Density of material of corrugated panel, lb/in.^{3}
29[2]	Real	GINSRT	Weight of honeycomb inserts, lb/100 inserts
	Real	TCORE	Thickness of panel honeycomb core, in.
	Real	TEDGE	Thickness of panel edge piece, in.

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
	Real	PCORE	Density of material of honeycomb core, lb/in.^{3}
	Real	PEDGE	Density of material of edge pieces, lb/in.^{3}
	Real	PSKIN1	Density of material of skin panel, lb/in.^{3}
	Real	PSKIN2	Density of material of corrugated panel, lb/ft^3
29[3]	Integer	NRIBS	Number of panel ribs
	Real	HRIB	Height of panel rib, in.
	Real	TEDGE	Thickness of panel edge piece, in.
	Real	PRIB	Density of rib material, lb/in.^{3}
	Real	PEDGE	Density of material of edge piece, lb/in.^{3}
	Real	PSKIN1	Density of material of skin panel, lb/in.^{3}
	Real	E1RIB	Width of panel rib, outside leg, in.
	Real	E2RIB	Width of panel rib, base leg, in.
	Real	E3RIB	Width of panel rib, inside leg, in.
	Real	T1RIB	Thickness of panel rib, outside leg, in.
	Real	T2RIB	Thickness of panel rib, base leg, in.
	Real	TWRIB	Thickness of panel rib, web, in.
30[1]	Real	GBOLT	Weight of bolts, lb/100 bolts
	Real	GNUTPL	Weight of nutplates, lb/100 nutplates
	Real	GWASH	Weight of washers, lb/100 washers
	Real	TCORN	Thickness of corner piece, in.
	Real	TPOST	Thickness of wall of corner post, in.
	Real	PPOST	Density of material of corner post, lb/in.^{3}
	Real	ODPOST	Outside diameter of corner post, in.
	Real	TPLATE	Thickness of corner plates
	Real	TFNG1	Thickness of support tube flange, in.
		TTUBE	Thickness of wall of support tube, in.
		PTUBE	Density of material of support tube, lb/in.^{3}

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
		LTUBE	Length of support tube, in.
		TSEAL	Thickness of seal strip, in.
		PSEAL	Density of material of seal strip, $lb/in.^3$
		TDOUBC	Thickness of long beam doubler channel, in.
		TDOUBP	Thickness of corner doubler plate, in.
	Real	TBMLA	Thickness of long beam, A, in.
		TBMSA	Thickness of short beam, A, in.
		HBEAMA	Height of long and short beams A, in.
		WBEAMA	Width of long and short beam A, in.
		PBM	Density of material of beams, $lb/in.^3$
30[2]	Real	GBOLT	Weight of bolts, lb/100 bolts
		GNUTPL	Weight of nutplates, lb/100 nutplates
		GWASH	Weight of washers, lb/100 washers
		GINSUL	Weight of insulators, lb/100 insulators
		TPOST	Thickness of wall of corner post, in.
		PPOST	Density of material of corner post, $lb/in.^3$
		WPOST	Width of post B, in.
30[3]		GBOLT	Weight of bolts, lb/100 bolts
		GNUTPL	Weight of nutplates, lb/100 nutplates
		GWASH	Weight of washers, lb/100 washers
		GCLAMP	Weight of clamping washers, lb/100 washers
		TPOST	Thickness of wall of corner post
	Real	PPOST	Density of material of corner post, $lb/in.^3$
		ODPOST	Outside diameter of corner post, in.
		ODPOSR	Outside diameter of center post, in.
		ODRING	Outside diameter of post support ring, in.
		HRING	Height of post support ring, in.

Table 3-1. Input Symbols, continued

Record	Variable Type	Symbol	Definition
		TFNG1	Thickness of support tube flange, in.
		TTUBE	Thickness of wall of support tube, in.
		PTUBE	Density of material of support tube, lb/in.^{3}
		IDFNG1	Outside diameter of support tube, corner post C, in.
		IDFNG2	Outside diameter of support tube, center post C, in.
		HFNG1	Height of support tube flange, corner post C, in.
		HFNG2	Height of support tube flange, center post C, in.
		TRING1	Thickness of post support ring, corner post C, in.
		TRING2	Thickness of post support ring, center post C, in.

Table 3-2. Input Records Format

Record	Data	I,J,K Range	Format
1	JI, TITLE		I1,9A8,A7
2	ICONF, IQCON, IQINP, ITURB IWALT, NANG, NCOLM, NMAT, NRSG NCRC, NSECT, NINS, NF, NPRT		20I4
3	DNX, DNY, DNZ, XDST, DIAM, AROD, XEMIS, FACC		10F8.0
4	STAAT, DELTA, WROTE, STOOP		10F8.0
5	AS, R, HH, TS, TC, SL, SLS, BE		10F8.0
6	F07, UF, DST, EALL, CRN, BF, BFL, BL		10F8.0
7	TALLW(I)	1-NMAT	10F8.0
8	EMIS(I)	1-NMAT	10F8.0
9	RHO(I)	1-NMAT	10F8.0
10	ID(I,J), MPT(I,J)	I = 1 - NMAT J = 1-8	20I4

Table 3-2. Input Record Format, continued

Record	Data	I,J,K Range	Format
11	AX(I,J,K)	I = 1-NMAT J = 1-8 K = 1-MPT(I,J)	10F8.0
12	AY(I,J,K)	I = 1-NMAT J = 1-8 K = 1-MPT(I,J)	10F8.0
13	X(I)	1-NCOLM	10F8.0
14	QCONL(I)	1-NCOLM	10F8.0
15	QCONT(I)	1-NCOLM	10F8.0
16	Y(I)	1-NSEG	10F8.0
17	MAT(I,J), TAMP(I,J)	I = 1-NCOLM J = 1-NSEG	9(I2, F6.0)
18	NR(I), NI(I), MR(J,I), VFACT(J,I)	I = 1-NRSG J = 1-NI(I)	I2, I6, 9(I2, F6.0)
19	IPFI, IPF(1), IPF(2), IPF(3), IPF(4), IPAD, KFLEX, NPAN		20I4
20	DT(1), XL, REY, VU, QL, AMACH		10F8.0
21	DT(2), TT, WER, D, VS, XI, DVEH, YCYL, DREF		10F8.0
22	DT(3), AE, VJ, WEJ, VV, TJ, XJ, YP		10F8.0
23	DT(4)		10F8.0
24	HPAN, HC, AI, AIY, AW, BW, EP		10F8.0
25	C(1), C(2), C(3), C(4), RHOP		10F8.0
26	TIME(I), ALT(I), VINF(I), ALPHA(I), BETA(I), HINSD(I), TINSD(I), NREADT	1-NTRAJ	7F8.0, I24
27	KINDP, KINDS, LENGTH, WIDTH, DLPANL, DWPANL, A, B		2I4, 6E8.0
28	PINS1, PINS2, PINS3		10E8.0
29[1]	NRIBS, CHORD, RADIUS PSKIN1, PSKIN2		I8, 9E8.0

Table 3-2. Input Record Format, continued

Record	Data	I,J,K Range	Format
29^2	GINSRT, TCORE, TEDGE, PCORE, PEDGE, PSKIN1, PSKIN2		10E8.0
29^3	NRIBS, HRIB, TEDGE, PRIB, PEDGE, PSKIN1		I8, 9E8.0
	E1RIB, E2RIB, E3RIB TIRIB, T2RIB, TWRIB		10E8.0
30^1	GBOLT, GNUTPL, GWASH, TCORN, TPOST, PPOST, ODPOST, TPLATE		10E8.0
30^2	TFNG1, TTUBE, PTUBE, LTUBE, TSEAL, PSEAL, TDOUBC, TDOUBP		10E8.0
30^3	GBOLT, GNUTPL, GWASH, GCLAMP, TPOST, PPOST, ODPOST, ODPOSR, ODRING, HRING, TFNG1, TTUBE, PTUBE, IDFNG1, IDFNG2, HFNG1, HFNG2, TRING1, TRING2		10E8.0

NOTE: In tables 3-1 and 3-2, the superscripts on record 29 denote values of the panel index KINDP whereas those on record 30 show values of the structural index KINDS.

RECORD	1–8	9–16	17–24	25–32	33–40	41–48	49–56	57–64	65–72	73–80
1	TITLE									
1	JJ TITLE									
2	ICONF IQCON	IQINP ITURB	IWALT NANG	NCOLM NSEG	NMAT NRSG	NCRC NSECT	NINS NF	NPRT		
3	DNX	DNY	DNZ	XDST	DIAM	AROD	XEMIS	FALL		
4	STAAT	DELTA	WROTE	STOOP						
5	AS	R	HH	TS	TC	SL	SLS	BE		
6	F07	UF	DST	EALL	CRN	BF	BFL	BL		
7	TALLW(1)	TALLW(2)	...	TALLW(NMAT)						
8	EMIS(1)	EMIS(2)	...	EMIS(NMAT)						
9	RHO(1)	RHO(2)	...	RHO(NMAT)						
10	ID(1,1) MPT(1,1)	ID(2,1) MPT(2,1)	... ...	ID(J,1) MPT(J,1)						
11	AX(1,1,1)	AX (2,1, 1)	...	AX(I,1,1)						
12	AY(1,1,1)	AY (2,1,1)	...	AY(I,1,1)						
	...	...	...	...						
12	AY(1,J,1)	AY(2,J,1)	...	AY(I,J,1)						
	REPORT RECORD 10 TO 12 FOR EACH MATERIAL									
13	X(1)	X(2)	...	X(I)						
14	QCONL(1)	QCONL(2)	...	QCONL(I)						
15	QCONT(1)	QCONT(2)	...	QCONT(I)						
16	Y(1)	Y(2)	...	Y(J)						
17	MAT(1,1) TAMP(1,1)	MAT(2,1) TAMP(2,1)	... ...	MAT(I,1) TAMP(I,1)						
17	... ...	... ...	... ...	... ...						
17	MAT(1,J) TAMP(1,J)	MAT(2,J) TAMP(2,J)	... ...	MAT(I,J) TAMP(I,J)						
18	NR(1) NI(1)	MR(1,1) VFACT(1,1)	MR(2,1) VFACT(2,1)	... ...	MR(M,1) VFACT(NI(1)N)					
18	... ...	... ...	... ...	... ...	... ...					
18	NR(N) NI(N)	MR(1,N) VFACT(1,N)	MR(2,N) VFACT(2,N)	... ...	MR(M,N) VFACT(NI(N),N)					
19	IPFI IPF(1)	IPF(2) IPF(3)	IPF(4) IPAD	KFLEX NPAN						
20	DT(1)	XL	REY	VU	QL	AMACH				
21	DT(2)	TT	WER	D	VS	XI	DVEH	YCL	DREF	
22	DT(3)	AE	VJ	WEJ	VV	TJ	XJ	YP		
23	DT(4)									
24	HPAN	HC	AI	AIY	AW	BW	EP			
25	C(1)	C(2)	C(3)	C(4)	RHOP					
26	TIME(1)	ALT(1)	VINF(1)	AOPHA(1)	BETA(1)	HINSD(1)	TINSD(1)			
26	...	...	...	...	...	...	...			
26	TIME(K)	ALT(K)	VINF(K)	ALPHA(K)	BETA(K)	HINSD(K)	TINSD(K)			NREADT

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Figure 3-1. Sample Chart for Standard Input Formats

COMMENT	1–8	9–16	17–24	25–32	33–40	A	B			
27	KINDP KINDS	LENGTH	WIDTH	DLPANEL	DWPANL	A	B			
28	PINS1	PINS2	*PINS1*							
29^1	NRIBS	CHORD	RADIUS	PSKIN1	PSKIN2					
29^2	GINSRT	TCORE	TEDGE	PCORE	PEDGE	PSKIN1	PSKIN2			
29^3	NRIBS	HRIB	TEDGE	PRIB	PEDGE	PSKIN1	PSKIN2			
29^3	E1RIB	E2RIB	E3RIB	T1RIB	T2RIB	TWRIB				
30^1	GBOLT	GNUTPL	GWASH	TCORN	TPOST	PPOST	ODPOST	TPLATE		
30^1	TFNG1	TTUBE	PTUBE	LTUBE	TSEAL	PSEAL	TDOUBC	TDOUBP		
30^1	TBMLA	TBMSA	HBEAMA	WBEAMA	PBM					
30^2	GBOLT	GNUTPL	GWASH	GINSUL	TPOST	PPOST	WPOST			
30^3	GBOLT	GNUTPL	GWASH	GCLAMP	TPOST	PPOST	ODPOST	ODPOSR	ODRING	HRING
30^3	TFNG1	TTUBE	PTUBE	IDFNG1	IDFNG2	HFNG1	HFNG2	TRING1	TRING2	

NOTE: SUPERSCRIPTS ON RECORD 29 DENOTE VALUES OF THE PANEL INDEX KINDP WHEREAS THOSE ON RECORD 30 SHOW VALUES OF THE STRUCTURAL INDEX KINDS.

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Figure 3-1. Sample Chart for Standard Input Formats, Contd

RECORD	1–8	9–16	17–24	25–32	33–40	41–48	49–56	57–64	65–72	73–80
1	TITLE									
1	2 TITLE									
	$ DATANU NUDIM = 1, NUTRAJ = 2,									
	ICOF = 2, IQCON = 3, NANG = 2,									
	XDST = 1.0, DELTA = 10.0, WROTE = 10.0, AS - 3.0, R = 2.5$									
13	X(1)	X(2)	...	X(I)						
14	QCONL(1)	QCONL(2)	...	QCONL(I)						
15	QCONT(1)	QCONT(2)	...	QCONT(I)						
16	Y(1)	Y(2)	...	Y(J)						
17	MAT(1,1) TAMP(1,1)	MAT(2,1) TAMP(2,1)	... ...	MAT(I,1) TAMP(I,1)						
17	... ...	... ...	... ...	... ...						
17	MAT(1,J) TAMP(1,J)	MAT(2,J) TAMP (2,J)	... ...	MAT(I,J) TAMP (I,J)						
18	NR(1) NI(1)	MR(1,1) VFACT (1,1)	MR(2,1) VFACT(2,1)	... ...	MR(M,1) VFACT(M,1)					
18	... ...	... ...	... ...	... ...	... ...					
18	NR(N) NI(N)	MR(1,N) VFACT(1,N)	MR(2,N) VFACT(2,N)	... ...	MR(M,N) VFACT(M,N)					
26	TIME (1)	ALT(1)	VINF (1)	ALPHA(1)	BETA(1)	HIND(1)	TIND(1)			
26	...	...	...	...	...	...	...			
26	TIME (K)	ALT(K)	VINF (K)	ALPHA(K)	BETA(K)	HIND(K)	TIND(K)			NREADT
27	KINDP KINDS	LENGTH	WIDTH	DLPANEL	DWPANEL	A	B			
28	PINS1	PINS2	PINS1							
29^1	NRIBS	CHORD	RADIUS	PSKIN1	PSKIN2					
29^2	GINSRT	TCORE	TEDGE	PCORE	PEDGE	PSKIN1	PSKIN2			
29^3	NRIBS	HRIB	TEDGE	PRIB	PEDGE	PSKIN1	PSKIN2			
29^3	E1RIB	E2RIB	E3RIB	T1RIB	T2RIB	TWRIB				
30^1	GBOLT	GNUTPL	GWASH	TCORN	TPOST	PPOST	ODPOST	TPLATE		
30^1	TFNG1	TTUBE	PTUBE	LTUBE	TSEAL	PSEAL	TDOUBC	TDOUBP		
30^1	TBMLA	TBMSA	HBEAMA	WBEAM	PBM					
30^2	GBOLT	GNUTPL	GWASH	GINSUL	TPOST	PPOST	WPOST			
30^3	GBOLT	GNUTPL	GWASH	GCLAMP	TPOST	PPOST	ODPOST	ODPOSR	ODRING	HRING
30^3	TFNG1	TTUBE	PTUBE	IDFNG1	IDFNG2	HFNG1	HFGN2	TRING1	TRING2	

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Figure 3-2. Sample Chart for Simplified Input Format

Table 3-3. Output Symbols

Symbol	Definition
TAU	Time in trajectory for which output is given, sec
AL	Altitude, ft
VI	Free-stream velocity, ft/sec
AOFA	Angle of attack, degrees
PI	Free-stream static pressure, psia
AMI	Free-stream Mach number
AME	Local Mach number
RYI	Free-stream Reynolds number/ft
PE	Local static pressure, psia
Q(I)	Boundary convective heat transfer rate at Ith Column, Btu/ft^2-sec
QNET(I)	Net external surface heat transfer at Ith Column, Btu/ft^2-sec
TEMP(I, J)	Temperature of Ith Column and Jth Segment at time TAU
A	Section area of the element C stress analysis, in.^{2}
XX	X-coordinate of the element, in.
ZZ	Z-coordinate of the element, in.
T	Temperature of the element, °R
FT	Thermal stress
FNET	Total stress
EDOT	Creep rate
FTU	Ultimate tensile strength, lb/in.^{2}
FCY	Yield strength, lb/in.^{2}
E	Youngs modules, lb/in.^{2}
TIMS	Design factor for ultimate tension
Y2MS	Design factor for yield strength
C3MS	Design factor for ultimate compression
C4MS	Design factor for bucking of corrugation
F5MS	Design factor for crippling of flange
F6MS	Design factor for crippling of flange

Table 3-3. Output Symbols, continued

Symbol	Definition
WBMS	Creep rate
DMAX	Maximum deflection
EMS	Minimum of margins of safety
EMAX	Total creep strain
TS	Corrugation thickness, in.
TC	Skin thickness, in.

SECTION 4

SAMPLE PROBLEM

This problem concerns sizing a section of circular arc corrugation panel on the bottom centerline of the space shuttle booster. Figure 4-1 shows the panel corrugations. The panel is made of Rene' 41. For an initial trial, a thickness of 0.040 inch is used. Figure 4-2 shows the conduction matrix which is used for structural temperature response. QCONL(I) is used to accommodate the separation and reattachment of flow on the corrugations. For internal radiation, it is assumed (for simplicity) that each surface element interacts only with the base element at the same column. The inner surface is assumed to be an aluminum LO_2 tank which is kept at 168°R until all the liquid oxygen is evacuated at 194 seconds in the trajectory. Figures 4-3 through 4-11 show the input, card images of the input, and output of the sample problem.

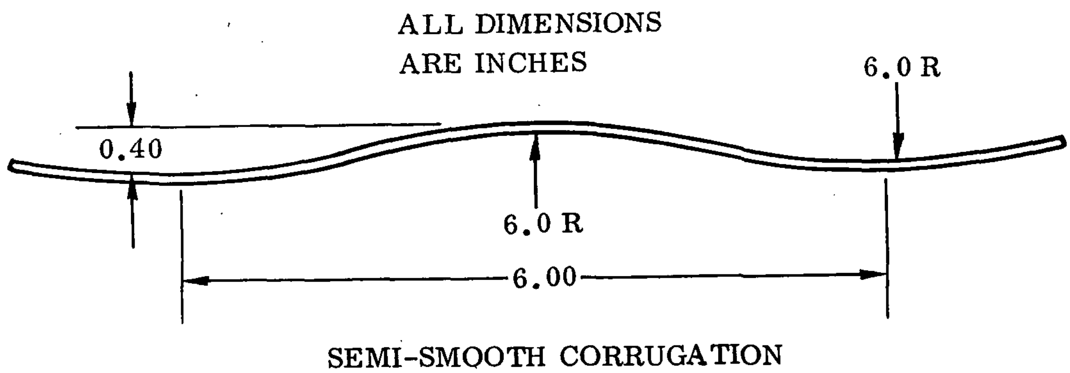

Figure 4-1. Corrugation

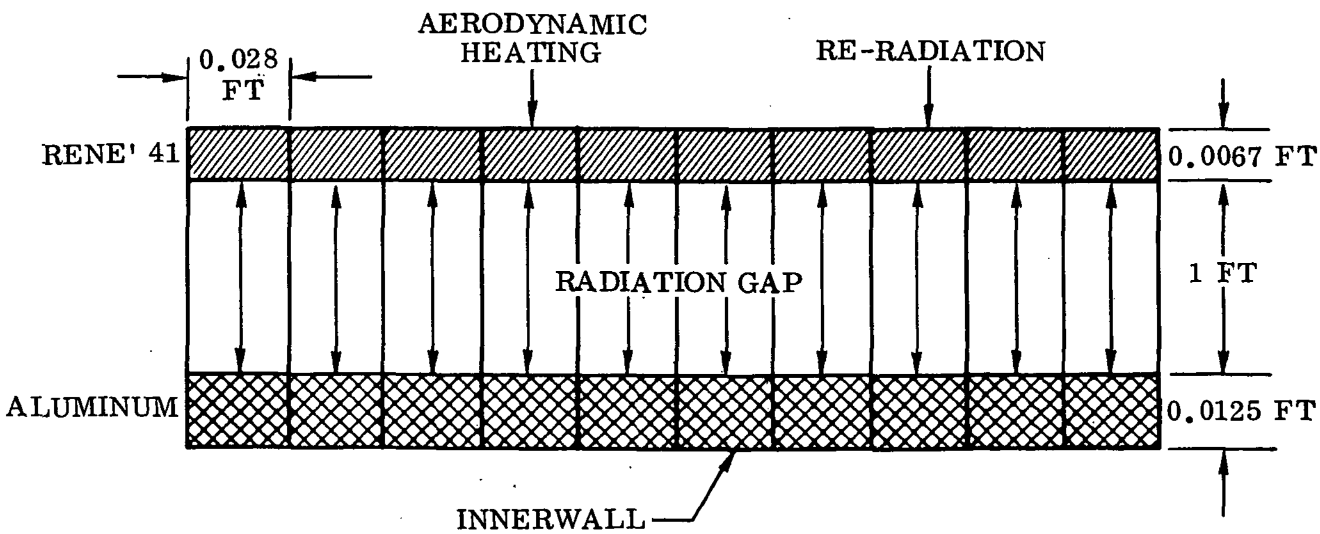

Figure 4-2. Conduction Modes

RECORD	Field 1	Field 2	Field 3	Field 4	Field 5	Field 6	Field 7	Field 8	Field 9	Field 10
1	1 SAMPLE	PROBLEM								
2	1 2	1 1	2 1	9 3	2 18	1 6	100	1		
3	0.0	0.0	1.0	32.0	32.0	.01	.85			
4	0.0	0.5	10.0	640.0						
5	6.0	6.0	0.4		0.04	30.0	15.0			
6	1.36E5	1.4	.005	.005	20.0					
7	2110.0	660.0								
8	0.85	0.2								
9	515.0	170.0								
10	2 1	2 8	1 8	1 8	1 8	1 8	2 7	1 7		
11	540.0									
12	0.108									
11	540.0	660.0	860.0	1060.0	1260.0	1460.0	1660.0	1860.0		
12	5.26	6.01	7.26	8.50	9.75	10.99	12.24	13.49		
12	31.60+6	31.00+6	30.00+6	28.75+6	27.65+6	26.20+6	24.60+6	22.75+6		
12	6.22-6	6.40-6	6.70-6	7.00-6	7.31-6	7.62-6	7.93-6	8.23-6		
12	1.35+5	1.33+5	1.31+5	1.31+5	1.31+5	1.31+5	1.30+5	1.08+5		
12	1.65+5	1.62+5	1.56+5	1.53+5	1.51+5	1.51+5	1.48+5	1.26+5		
11	6.0+3	1.0+4	2.0+4	3.0+4	5.0+4	7.0+4	9.0+4			
12	47.25+3	46.00+3	44.15+3	42.90+3	41.05+3	39.60+3	38.00+3			
12	48.05+3	46.70+3	44.70+3	43.35+3	41.45+3	39.90+3	38.30+3			
10	2 1	1 1								
11	540.0									
12	0.24									
12	70.0									
13	.028	.028	.028	.028	.028	.028	.028	.028	.028	
14	2.0	1.75	1.25	1.1	1.0	0.9	0.8	0.75	0.7	
16	.0067	1.0	0.0125							
17	1 490.0	1 490.0	1 490.0	1 490.0	1 490.0	1 490.0	1 490.0	1 490.0	1 490.0	
17	0 490.0	0 490.0	0 490.0	0 490.0	0 490.0	0 490.0	0 490.0	0 490.0	0 490.0	
17	2 168.0	2 168.0	2 168.0	2 168.0	2 168.0	2 168.0	2 168.0	2 168.0	2 168.0	
18	11 113	1.0								

STANDARD KEYPUNCH WORKSHEET
FORM 5363 (4-66)

Figure 4-3. Input for Sample Problem

```
RECORD  1234567890123456789012345678901234567890123456789012345678901234567890123456789012
  18    21     123   1.0
  18    31     133   1.0
  18    41     143   1.0
  18    51     153   1.0
  18    61     163   1.0
  18    71     173   1.0
  18    81     183   1.0
  18    91     193   1.0
  18    13     111   1.0
  18    23     121   1.0
  18    33     131   1.0
  18    43     141   1.0
  18    53     151   1.0
  18    63     161   1.0
  18    73     171   1.0
  18    83     181   1.0
  18    93     191   1.0
  19       4   1   2   3   4   0   0   1
  20       100.0   100.0   1.0E7  8000.0  1400.0     6.0
  21        40.0   1.0E6  1000.0    12.0   100.0   100.0    40.0
  22        20.0     3.0  1200.0   200.0   650.0   1.0E4    20.0    10.0
  23        10.0
  24         0.1    0.01   0.001   0.002     3.0     2.0   1.0E7
  25      254.56 -62.717  4.4189-.025179   180.0
  26         0.0   368.0     0.0     0.0     0.0   1.0E6   168.0
  26         ...     ...     ...     ...     ...     ...     ...
  26       184.0 2.167E5  9047.0     0.0     0.0   1.0E6   168.0
  26       199.0 2.234E5  9021.0     7.5     0.0     0.0     0.0
  26         ...     ...     ...     ...     ...     ...     ...
  26       638.0 1.991E5   596.4     8.0     0.0     0.0     0.0                       9
  27       1   1    30.0   15.00     1.0     1.0    0.50    0.50
  28
```

STANDARD KEYPUNCH WORKSHEET
FORM 5363 (4-66)

Figure 4-3. Input for Sample Problem, Contd

RECORD	Cols 1–10	Cols 11–20	Cols 21–30	Cols 31–40	Cols 41–50	Cols 51–60	Cols 61–70	Cols 71–80
29	5	2.00	6.00	0.30	0.30			
30	0.40	0.50	0.10	0.01	0.02	0.30	0.50	0.01
30	0.05	0.02	0.30	0.60	0.01	0.30	0.01	0.01
30	0.01	0.01	0.50	1.00	0.30			

STANDARD KEYPUNCH WORKSHEET
FORM 5363 (4-66)

Figure 4-3. Input for Sample Problem, Contd

```
      TPS - CORRUGATIONS
  1    2    1    1    2    1    9    3    2   18    1    6       100
       0         0         1        32        32       .01       .85
       0        .5        10       640
       6         6        .4                 .04        30        15
  1.36E5   1.4      .005      .005            20
    2110       660
     .85        .2
     515       170
   2    1    2    8    1    8    1    8    1    8    1    8    2    7    1    7
     540
    .108
     540       660       860      1060      1260      1460      1660      1860
    5.26      6.01      7.26      8.50      9.75     10.99     12.24     13.49
31.60+6   31.00+6   30.00+6   28.75+6   27.65+6   26.20+6   24.60+6   22.75+6
 6.22-6    6.40-6    6.70-6    7.00-6    7.31-6    7.62-6    7.93-6    8.23-6
 1.35+5    1.33+5    1.31+5    1.31+5    1.31+5    1.31+5    1.30+5    1.08+5
 1.65+5    1.62+5    1.56+5    1.53+5    1.51+5    1.51+5    1.48+5    1.26+5
    6000     10000     20000     30000     50000     70000     90000
47.25+3   46.00+3   44.15+3   42.90+3   41.05+3   39.60+3   38.00+3
48.05+3   46.70+3   44.70+3   43.35+3   41.45+3   39.90+3   38.30+3
   2    1    1    1
     540
     .24
      70
    .028      .028      .028      .028      .028      .028      .028      .028      .028
     2.0      1.75      1.25      1.10      1.00        .9        .8       .75        .7
   .0067         1     .0125
 1   490 1     490 1     490 1     490 1     490 1     490 1     490 1     490 1     490
 0   490 0     490 0     490 0     490 0     490 0     490 0     490 0     490 0     490
 2   168 2     168 2     168 2     168 2     168 2     168 2     168 2     168 2     168 2     168
11        113         1
21        123         1
31        133         1
41        143         1
51        153         1
61        163         1
71        173         1
81        183         1
91        193         1
13        111         1
23        121         1
33        131         1
43        141         1
53        151         1
63        161         1
73        171         1
83        181         1
93        191         1
   4    1    2    3    4    0    0    1
    100.      100.      1.E7     8000.     1400.        6.
     40.      1.E6     1000.       12.      100.       20.       40.
     20.        3.     1200.      200.      650.      1.E4       10.       10.
     10.
     0.1      0.01      .001      .002       2.5      1.25      1.E7
  254.56   -62.717   4.4189-.025179          180.
     0.0     368.0       0.0       0.0       0.0      1.E9     168.0
    40.0    0681.0     499.3       0.0       0.0      1.E9     168.0
    80.0   41750.0    1299.0       0.0       0.0      1.E9     168.0
   120.0   96470.0    3063.0       0.0       0.0      1.E9     168.0
```

Figure 4-4. Card Images of Input to Sample Problem

```
 160.0163500.0  5994.0     0.0     0.0   1.E9   168.0
 174.0186500.0  7234.0     0.0     0.0   1.E9   168.0
 182.0199100.0  7954.0     0.0     0.0   1.E9   168.0
 190.0211000.0  8681.0     0.0     0.0   1.E9   168.0
 194.0216700.0  9047.0     0.0     0.0   1.E9   168.0
194.25217030.0  9045.7     0.4     0.0    0.0     0.0
 199.0223400.0  9021.0     7.5     0.0    0.0     0.0
 209.0234700.0  8971.0    22.5     0.0    0.0     0.0
 219.0243300.0  8927.0    37.5     0.0    0.0     0.0
 229.0249300.0  8892.0    52.5     0.0    0.0     0.0
 244.0253000.0  8856.0    60.0     0.0    0.0     0.0
 264.0248500.0  8842.0    60.0     0.0    0.0     0.0
 284.0233200.0  8849.0    60.0     0.0    0.0     0.0
 304.0207400.0  8826.0    60.0     0.0    0.0     0.0
 324.0172500.0  8593.0    60.0     0.0    0.0     0.0
 344.0134200.0  7436.0    60.0     0.0    0.0     0.0
 354.0118600.0  6450.0    40.7     0.0    0.0     0.0
 364.0107300.0  5647.0    31.9     0.0    0.0     0.0
 374.0100500.0  4898.0    30.5     0.0    0.0     0.0
 384.0  97150.0  4122.0    35.0     0.0    0.0     0.0
 394.0  94380.0  3255.0    46.2     0.0    0.0     0.0
 404.0  91360.0  2411.0    44.6     0.0    0.0     0.0
 414.0  87450.0  1971.0    38.1     0.0    0.0     0.0
 424.0  82320.0  1731.0    29.5     0.0    0.0     0.0
 434.0  75890.0  1596.0    24.7     0.0    0.0     0.0
 444.0  68370.0  1497.0    21.3     0.0    0.0     0.0
 454.0  60160.0  1406.0    17.9     0.0    0.0     0.0
 464.0  52030.0  1305.0    14.1     0.0    0.0     0.0
 474.0  46810.0  1174.0     9.1     0.0    0.0     0.0
 484.0  44560.0  1048.0     5.0     0.0    0.0     0.0
 494.0  43010.0   962.0     5.0     0.0    0.0     0.0
 504.0  41040.0   918.0     5.0     0.0    0.0     0.0
 514.0  38350.0   903.7     5.0     0.0    0.0     0.0
 524.0  35080.0   899.5     5.0     0.0    0.0     0.0
 534.0  31520.0   895.7     5.0     0.0    0.0     0.0
 544.0  27860.0   886.6     5.2     0.0    0.0     0.0
 554.0  24560.0   861.2     5.5     0.0    0.0     0.0
 564.0  22190.0   814.4     6.1     0.0    0.0     0.0
 574.0  21140.0   745.9     6.8     0.0    0.0     0.0
 584.0  21440.0   658.3     7.6     0.0    0.0     0.0
 594.0  22600.0   556.6     8.0     0.0    0.0     0.0
 604.0  23570.0   467.9     8.0     0.0    0.0     0.0
 624.0  22310.0   504.1     8.0     0.0    0.0     0.0
 638.0  19910.0   596.4     8.0     0.0    0.0     0.0          9
 1    1   30.00   15.00    1.00    1.00   0.50    0.50

      5    2.00    6.00    0.30    0.30
   0.40    0.50    0.10    0.01    0.02   0.30    0.50    0.01
   0.05    0.02    0.30    0.60    0.01   0.30    0.01    0.01
   0.01    0.01    0.50    1.00    0.30
```

Figure 4-4. Card Images of Input to Sample Problem, Contd

***** T R A J E C T O R Y   I N P U T *****

I	TIME(I)	ALT(I)	VINF(I)	ALPHA(I)	BETA(I)	HINSD(I)	TINSD(I)
1	0	368	0	0.0000	0.0000	1.0000E+09	168.0000
2	40	9681	499	0.0000	0.0000	1.0000E+09	168.0000
3	80	41750	1299	0.0000	0.0000	1.0000E+09	168.0000
4	120	96470	3063	0.0000	0.0000	1.0000E+09	168.0000
5	160	163500	5994	0.0000	0.0000	1.0000E+09	168.0000
6	174	186500	7234	0.0000	0.0000	1.0000E+09	168.0000
7	182	199100	7954	0.0000	0.0000	1.0000E+09	168.0000
8	190	211000	8581	0.0000	0.0000	1.0000E+09	168.0000
9	194	216700	9047	0.0000	0.0000	1.0000E+09	168.0000
10	194	217070	9046	.4000	0.0000	0.	0.0000
11	199	223400	9321	7.5000	0.0000	0.	0.0000
12	209	234700	8971	22.5000	0.0000	0.	0.0000
13	219	243300	8927	37.5000	0.0000	0.	0.0000
14	229	249300	8892	52.5000	0.0000	0.	0.0000
15	244	253000	8856	60.0000	0.0000	0.	0.0000
16	264	248500	8842	60.0000	0.0000	0.	0.0000
17	284	233200	8849	60.0000	0.0000	0.	0.0000
18	304	207400	8826	60.0000	0.0000	0.	0.0000
19	324	172500	8593	60.0000	0.0000	0.	0.0000
20	344	134200	7436	60.0000	0.0000	0.	0.0000
21	354	118600	6450	40.7000	0.0000	0.	0.0000
22	364	107300	5647	31.9000	0.0000	0.	0.0000
23	374	100500	4898	30.5000	0.0000	0.	0.0000
24	384	97150	4122	35.0000	0.0000	0.	0.0000
25	394	94380	3255	46.2000	0.0000	0.	0.0000
26	404	91360	2411	44.6000	0.0000	0.	0.0000
27	414	87450	1971	38.1000	0.0000	0.	0.0000
28	424	82320	1731	29.5000	0.0000	0.	0.0000
29	434	75890	1596	24.7000	0.0000	0.	0.0000
30	444	68370	1497	21.3000	0.0000	0.	0.0000
31	454	60160	1406	17.9000	0.0000	0.	0.0000
32	464	52030	1305	14.1000	0.0000	0.	0.0000
33	474	46810	1174	9.1000	0.0000	0.	0.0000
34	484	44560	1048	5.0000	0.0000	0.	0.0000
35	494	43010	962	5.0000	0.0000	0.	0.0000
36	504	41040	918	5.0000	0.0000	0.	0.0000
37	514	38350	904	5.0000	0.0000	0.	0.0000
38	524	35080	899	5.0000	0.0000	0.	0.0000
39	534	31520	896	5.0000	0.0000	0.	0.0000
40	544	27860	887	5.2000	0.0000	0.	0.0000
41	554	24560	861	5.5000	0.0000	0.	0.0000
42	564	22190	814	6.1000	0.0000	0.	0.0000
43	574	21140	746	6.8000	0.0000	0.	0.0000
44	584	21440	658	7.6000	0.0000	0.	0.0000
45	594	22600	557	8.0000	0.0000	0.	0.0000
46	604	23570	468	8.0000	0.0000	0.	0.0000
47	624	22310	504	8.0000	0.0000	0.	0.0000
48	639	19910	596	8.0000	0.0000	0.	0.0000

Figure 4-5. Output of Sample Problem - Input Data

```
PROGRAM OPTIONS USED
   CONFIGURATION-      PLATE
   TURBULENT HEATING-  ECKERT
   WALL TEMPERATURE-   NONUNIFORM
   ANGLE OF ATTACK-    VARIED
   LOCAL HEAT FLUX-    CALCULATED

DIRECTION COSINES OF OUTER NORMAL FROM SURFACE
   DNX =  0.0000
   DNY =  0.0000
   DNZ =  1.0000

DISTANCE FROM LEADING EDGE        32.0000 FT
BODY DIAMETER                     32.0000 FT
SHOULDER RADIUS/BODY DIAMETER       .0100
EXTERNAL SURFACE EMISSIVITY         .85

INITIAL TIME                         0.0 SEC
END TIME                           640.0 SEC
CALCULATION TIME INTERVAL             .5 SEC
PRINT OUT INTERVAL                  10.0 SEC


***** M A T E R I A L   P R O P E R T I E S *****

MATERIAL NUMBER        -1-        -2-

ALLOWABLE TEMP. R   2110.000    660.000

EMISSIVITY              .850       .200

MATERIAL DENSITY     515.000    170.000
```

MATERIAL NUMBER	HEAT CAPACITY AX	HEAT CAPACITY AY	THERMAL CONDUCTIVITY AX	THERMAL CONDUCTIVITY AY	YOUNGS MODULUS AX	YOUNGS MODULUS AY	THERMAL EXPANSION COEF AX	THERMAL EXPANSION COEF AY
1	5.400E+02	1.080E-01	5.430E+02	5.260E+00	5.400E+02	3.160E+07	5.400E+02	6.220E-06
	0.	0.	6.600E+02	6.010E+00	6.600E+02	3.100E+07	6.600E+02	6.400E-06
	0.	0.	8.600E+02	7.260E+00	8.600E+02	3.000E+07	8.600E+02	6.700E-06
	0.	0.	1.060E+03	8.500E+00	1.060E+03	2.875E+07	1.060E+03	7.000E-06
	0.	0.	1.260E+03	9.750E+00	1.260E+03	2.765E 07	1.260E+03	7.310E-06
	0.	0.	1.460E+03	1.099E+01	1.460E+03	2.620E+07	1.460E+03	7.620E-06
	0.	0.	1.660E+03	1.224E+01	1.660E+03	2.460E+07	1.660E+03	7.930E-06
	0.	0.	1.860E+03	1.349E+01	1.860E+03	2.275E+07	1.860E+03	8.230E-06
	0.	0.	0.	0.	0.	0.	0.	0.
2	5.400E+02	2.400E-01	5.400E+02	7.000E+01	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.

Figure 4-5. Output of Sample Problem - Input Data, Contd

0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.

MATERIAL NUMBER	YIELD STRENGTH AX	YIELD STRENGTH AY	ULT TENSILE STRENGTH AX	ULT TENSILE STRENGTH AY	LARSON-MILLER STRAIN 1 AX	LARSON-MILLER STRAIN 1 AY	LARSON-MILLER STRAIN 2 AX	LARSON-MILLER STRAIN 2 AY
1	5.400E+02	1.350E+05	5.400E+02	1.650E+05	6.000E+03	4.725E+04	6.000E+03	4.805E+04
	6.600E+02	1.330E+05	6.600E+02	1.620E+05	1.000E+04	4.600E+04	1.000E+04	4.670E+04
	8.600E+02	1.310E+05	8.600E+02	1.560E+05	2.000E+04	4.415E+04	2.000E+04	4.470E+04
	1.060E+03	1.310E+05	1.060E+03	1.530E+05	3.000E+04	4.290E+04	3.000E+04	4.335E+04
	1.260E+03	1.310E+05	1.260E+03	1.510E+05	5.000E+04	4.105E+04	5.000E+04	4.145E+04
	1.460E+03	1.310E+05	1.460E+03	1.510E+05	7.000E+04	3.960E+04	7.000E+04	3.990E+04
	1.660E+03	1.300E+05	1.660E+03	1.480E+05	9.000E+04	3.800E+04	9.000E+04	3.830E+04
	1.860E+03	1.080E+05	1.860E+03	1.260E+05	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.

***** C O N D U C T I O N   I N P U T *****

COLUMN NUMBER, I		-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-
WIDTH, X(I) FT		.0280	.0280	.0280	.0280	.0280	.0280	.0280	.0280	.0280
HEATING FACTORS										
LAMINAR		2.0	1.8	1.3	1.1	1.0	.9	.8	.8	.7
TURBULENT		2.0	1.8	1.3	1.1	1.0	.9	.8	.8	.7
SEG.NO., J =	-1-	1*	1	1	1	1	1	1	1	1
THICK.,Y(J) =	.0067	490**	490	490	490	490	490	490	490	490
	-2-	0	0	0	0	0	0	0	0	0
	1.0000	490	490	490	490	490	490	490	490	490
	-3-	2	2	2	2	2	2	2	2	2
	.0125	168	168	168	168	168	168	168	168	168

--NOTE--
* = MATERIAL NUMBER
** = INITIAL TEMPERATURE DEG R

***** R A D I A T I O N   I N T E R C H A N G E *****

Figure 4-5. Output of Sample Problem - Input Data, Contd

```
SEG NO.  NT    INTERCHANGE NEIGHBORS AND VIEW FACTORS

 (11)    1    (13) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (21)    1    (23) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (31)    1    (33) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (41)    1    (43) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (51)    1    (53) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (61)    1    (63) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (71)    1    (73) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (81)    1    (83) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (91)    1    (93) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (13)    1    (11) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (23)    1    (21) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (33)    1    (31) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (43)    1    (41) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (53)    1    (51) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (63)    1    (61) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (73)    1    (71) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (83)    1    (81) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (93)    1    (91) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000


***** S T R E S S   I N P U T *****

        AS           R          HH          TS          TC          SL         SLS          BE
  6.000E+00   6.000E+00   4.000E-01   -0.          4.000E-02   3.000E+01   1.500E+01   -0.

       E07          UF         DST        FALL         CRN          BF         BFL          BL
  1.360E+05   1.400E+00   5.000E-07   5.000E-03   2.000E+01   -0.          -0.          -0.


***** F A T I G U E   I N P U T *****

     IREAD       KFLEX        NPAN       DT(1)       DT(2)       DT(3)       DT(4)          XL
         0           0           1   1.000E+02   4.000E+01   2.000E+01   1.000E+01   1.000E+02

       REY          VU          QL       AMACH          TT         WER           D          VS
  1.000E+07   8.000E+03   1.400E+03   6.000E+00   1.000E+06   1.000E+03   1.200E+01   1.000E+02

        XI        OVEH          AF          VJ         WEJ          VV          TJ          XJ
  2.000E+01   4.000E+01   3.000E+00   1.200E+07   2.000E+02   6.500E+02   1.000E+04   1.000E+01

        VP        HPAN          HC          AI         AIY          AW          BW          EP
  1.000E+01   1.000E-01   1.000E-02   1.600E-03   2.000E-03   3.000E+00   2.000E+00   1.000E+07

                         C(1)        C(2)        C(3)        C(4)        RHOF
                    2.546E+02  -6.272E+01   4.419E+00  -2.518E-02   1.800E+02


***** E N D   O F   I N P U T *****
```


Figure 4-5. Output of Sample Problem - Input Data, Contd

TAU	AL	VI	AOFA	PI	AMT	AME	RYI	PE
1.0010E+01	2.6380E+03	1.2170E+02	0.	1.9360E+03	1.0837E-01	1.0811E-01	6.8805E+05	1.9360E+03

I	1	2	3	4	5	6	7	8	9
Q(I)	1.7245E-01	1.5227E-01	1.1057E-01	9.7924E-02	8.9364E-02	8.0717E-02	7.1995E-02	6.7622E-02	6.3213E-02
QNET(I)	1.4877E-01	1.2865E-01	8.7064E-02	7.4460E-02	6.5926E-02	5.7304E-02	4.8606E-02	4.4247E-02	3.9849E-02
TEMP(I,1)	4.9202E+02	4.9169E+02	4.9107E+02	4.9083E+02	4.9068E+02	4.9053E+02	4.9040E+02	4.9032E+02	4.9026E+02
TEMP(I,2)	4.9000E+02	4.9000E+02	4.9000E+02	4.9000E+02	4.9000E+02	4.9000E+02	4.9000E+02	4.9000E+02	4.9000E+02
TEMP(I,3)	1.6800E+02	1.6800E+02	1.6800E+02	1.6800E+02	1.6800E+02	1.6800E+02	1.6800E+02	1.6800E+02	1.6800E+02

A	XX	ZZ	T	FT	FNET	FDOT	FTU	FCY	E
1.243E-02	1.553E-01	2.011E-03	4.911E+02	1.229E+02	-8.677E+04	2.002E-61	1.650E+05	1.350E+05	3.160E+07
1.243E-02	4.656E-01	1.809E-02	4.917E+02	-8.550E+00	-7.984E+04	1.875E-62	1.650E+05	1.350E+05	3.160E+07
1.243E-02	7.746E-01	5.021E-02	4.920E+02	-9.611E+01	-6.583E+04	1.144E-64	1.650E+05	1.350E+05	3.160E+07
1.243E-02	1.082E+00	9.828E-02	4.917E+02	-6.173E+01	-4.470E+04	2.764E-68	1.650E+05	1.350E+05	3.160E+07
1.243E-02	1.386E+00	1.622E-01	4.911E+02	1.670E+01	-1.658E+04	2.038E-75	1.650E+05	1.350E+05	3.160E+07
1.243E-02	1.687E+00	2.378E-01	4.908E+02	1.491E+01	1.662E+04	1.887E-75	1.650E+05	1.350E+05	3.160E+07
1.243E-02	1.991E+00	3.017E-01	4.907E+02	2.152E+00	4.464E+04	1.794E-68	1.650E+05	1.350E+05	3.160E+07
1.243E-02	2.298E+00	3.498E-01	4.905E+02	-1.851E+00	6.573E+04	6.218E-65	1.650E+05	1.350E+05	3.160E+07
1.243E-02	2.607E+00	3.819E-01	4.904E+02	3.515E+00	7.983E+04	1.155E-62	1.650E+05	1.350E+05	3.160E+07
1.243E-02	2.917E+00	3.980E-01	4.903E+02	8.042E+00	8.690E+04	1.593E-61	1.650E+05	1.350E+05	3.160E+07

Figure 4-6. Output of Sample Problem - Results

```
***** S T R E S S   A N A L Y S I S   N O T E *****

      T1MS        Y2MS        C3MS        C4MS        F5MS        F6MS        WRMS        DMAX         EMS        EMAX
 3.5630E-01  5.5358E-01  2.2251E-01 -4.7971E-01  1.0000E+02  1.0000E+02  1.0000E+02  7.2501E-01 -4.7971E-01  3.9461E-03

STRESS CONSTRAINTS EXCEEDED - PANEL THICKNESS RESIZED TO
   TC =  .041 IN.
   TS =-0.000 IN.

***** E N D   O F   N O T E *****

                    TAU          AL          VI        AOFA          PI         AMI         ANE         RYI          PE
             6.4090E+02  1.9610E+04  6.0794E+02  1.3963E-01  1.0266E+07  5.7029E-01  5.6837E-01  2.2096E+06  1.0266E+03

          T           1           2           3           4           5           6           7           8           9

       Q(I)  1.1000E-02 -3.0883E-02 -7.8664E-02 -1.2876E-01 -1.7467E-01 -2.0925E-01 -2.2828E-01 -2.4385E-01 -2.4356E-01
    QNET(I) -1.4225E-02 -5.6917E-02 -1.0635E-01 -1.5854E-01 -2.0670E-01 -2.4399E-01 -2.6554E-01 -2.8311E-01 -2.8401E-01

  TEMF(I,1)  4.9973E+02  5.0363E+02  5.1132E+02  5.2066E+02  5.3072E+02  5.4098E+02  5.5046E+02  5.5767E+02  5.6184E+02
  TEMF(I,2)  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02
  TEMF(I,3)  2.5335E+02  2.5336E+02  2.5337E+02  2.5339E+02  2.5341E+02  2.5343E+02  2.5344E+02  2.5346E+02  2.5346E+02

          A          XX          ZZ           T          FT        FNET        FDOT         FTU         FCY           E

  1.274E-02   1.553E-01   2.011E-03   5.113E+02  -2.634E+03  -4.760E+04   1.841E-64   1.650E+05   1.350E+05   3.160E+07
  1.274E-02   4.656E-01   1.809E-02   5.036E+02  -7.210E+02  -4.203E+04   9.180E-67   1.650E+05   1.350E+05   3.160E+07
  1.274E-02   7.746E-01   5.021E-02   4.997E+02   8.452E+02  -3.317E+04   4.132E-69   1.650E+05   1.350E+05   3.160E+07
  1.274E-02   1.082E+00   9.828E-02   5.036E+02   1.277E+03  -2.182E+04   2.952E-71   1.650E+05   1.350E+05   3.160E+07
  1.274E-02   1.386E+00   1.622E-01   5.113E+02   1.358E+03  -7.218E+03   3.505E-76   1.650E+05   1.350E+05   3.160E+07
  1.274E-02   1.687E+00   2.378E-01   5.207E+02   1.409E+03   1.002E+04   1.081E-72   1.650E+05   1.350E+05   3.160E+07
  1.274E-02   1.991E+00   3.017E-01   5.307E+02   1.022E+03   2.415E+04   3.816E-66   1.650E+05   1.350E+05   3.160E+07
  1.274E-02   2.298E+00   3.498E-01   5.410E+02   2.045E+02   3.425E+04   2.430E-62   1.650E+05   1.350E+05   3.160E+07
  1.274E-02   2.607E+00   3.819E-01   5.505E+02  -8.671E+02   4.042E+04   6.683E-60   1.647E+05   1.348E+05   3.155E+07
  1.274E-02   2.917E+00   3.980E-01   5.577E+02  -1.894E+03   4.299E+04   1.832E-58   1.646E+05   1.347E+05   3.151E+07
```

Figure 4-7. Output of Sample Problem - Results and Stress Redesign

```
***** S T R E S S   A N A L Y S I S   N O T E *****

      T1MS        Y2MS        C3MS        C4MS        F5MS        F6MS        W8MS        DMAX         EMS        EMAX
 3.9021E-01  5.9242E-01  2.5312E-01 -4.5335E-01  1.0000E+02  1.0000E+02  1.0000E+02  3.1707E-01 -4.5335E-01  3.7549E-08

 STRESS CONSTRAINTS EXCEEDED - PANEL THICKNESS RESIZED TO
    TC =  .060 IN.
    TS =-0.000 IN.

***** E N D   O F   N O T E *****

                   TAU          AL          VT        AOFA          PI         AMI         AME         RYI          PE
            6.4000E+02  1.9610E+04  6.0794E+02  1.3963E-01  1.0266E+03  5.7029E-01  5.6837E-01  2.2096E+06  1.0266E+03

          I          1           2           3           4           5           6           7           8           9

       Q(I)  1.1000E-02 -3.0883E-02 -7.8664E-02 -1.2876E-01 -1.7463E-01 -2.0925E-01 -2.2828E-01 -2.4385E-01 -2.4356E-01
    QNET(I) -1.4225E-02 -5.6917E-02 -1.0635E-01 -1.5854E-01 -2.0679E-01 -2.4399E-01 -2.6554E-01 -2.8311E-01 -2.8401E-01

  TEMP(I,1)  4.9973E+02  5.0363E+02  5.1132E+02  5.2066E+02  5.3072E+02  5.4098E+02  5.5046E+02  5.5767E+02  5.6184E+02
  TEMP(I,2)  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02
  TEMP(I,3)  2.5335E+02  2.5336E+02  2.5337E+02  2.5339E+02  2.5341E+02  2.5343E+02  2.5344E+02  2.5346E+02  2.5346E+02

          A          YX          ZZ           T          FT        FNET        EDOT         FTU         FCY           E

  1.867E-02   1.553E-01   2.011E-03   5.113E+02  -2.634E+03  -3.331E+04   3.965E-67   1.650E+05   1.350E+05   3.160E+07
  1.867E-02   4.656E-01   1.809E-02   5.036E+02  -7.210E+02  -2.891E+04   2.439E-69   1.650E+05   1.350E+05   3.160E+07
  1.867E-02   7.746E-01   5.021E-02   4.997E+02   8.452E+02  -2.236E+04   8.502E-72   1.650E+05   1.350E+05   3.160E+07
  1.867E-02   1.082E+00   9.828E-02   5.036E+02   1.277E+03  -1.448E+04   5.959E-74   1.650E+05   1.350E+05   3.160E+07
  1.867E-02   1.3[illegible]E+00   1.622E-01   5.113E+02   1.358E+03  -4.493E+03   5.485E-77   1.650E+05   1.350E+05   3.160E+07
  1.867E-02   1.6[illegible]E+00   2.378E-01   5.207E+02   1.409E+03   7.286E+03   1.820E-74   1.650E+05   1.350E+05   3.160E+07
  1.867E-02   1.991E+00   3.017E-01   5.307E+02   1.022E+03   1.680E+04   2.011E-68   1.650E+05   1.350E+05   3.160E+07
  1.867E-02   2.298[illegible]   3.498E-01   5.410E+02   2.045E+02   2.343E+04   9.522E-65   1.650E+05   1.350E+05   3.160E+07
  1.867E-02   2.607E+00   3.819E-01   5.505E+02  -8.671E+02   2.730E+04   2.225E-62   1.647E+05   1.348E+05   3.155E+07
  1.867E-02   2.917E+00   3.980E-01   5.577E+02  -1.894E+03   2.873E+04   5.324E-61   1.646E+05   1.347E+05   3.151E+07

***** S T R E S S   A N A L Y S I S   N O T E *****

      T1MS        Y2MS        C3MS        C4MS        F5MS        F6MS        W8MS        DMAX         EMS        EMAX
 1.0376E+00  1.3349E+00  8.3801E-01  1.7524E-01  1.0000E+02  1.0000E+02  1.0000E+02 -2.7696E-01  1.7524E-01  1.9868E-08

***** E N D   O F   N O T E *****
```

Figure 4-7. Output of Sample Problem - Results and Stress Redesign, Contd

```
FREQUENCY =    716.2 HZ

BOUNDARY LAYER NOISE =  121.6 DB - REYNOLDS NO. =    2.6744E+08, MACH NO. =    6.5537E-01
DYNAMIC PRESSURE =    3.3086E+02, VELOCITY =    7.0422E+02
ROCKET ENGINE NOISE =  123.1 DB - APPARENT NOISE SOURCE AT    40.8 FT
ABES NOISE =    73.3 DB
JET SCRUBBING NOISE =  127.1 DB

MAXIMUM BENDING STRESS =          442 PSI
MAXIMUM RMS DEFLECTION =      .00000 IN
BOUNDARY LAYER NOISE CRITICAL STRESS =   2.0790E+01 PSI
NO. OF STRESS REVERSALS =   1.1699E+06
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   3.1072E+04 PSI

MAXIMUM BENDING STRESS =          527 PSI
MAXIMUM RMS DEFLECTION =      .00000 IN
ROCKET ENGINE NOISE CRITICAL STRESS =   2.6068E+01 PSI
NO. OF STRESS REVERSALS =   4.4536E+05
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   3.6749E+04 PSI

MAXIMUM BENDING STRESS =            2 PSI
MAXIMUM RMS DEFLECTION =      .00000 IN
JET FLYBACK ENGINE NOISE CRITICAL STRESS =   4.8264E-04 PSI
NO. OF STRESS REVERSALS =   3.8919E+07
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   2.2093E+04 PSI

MAXIMUM BENDING STRESS =          832 PSI
MAXIMUM RMS DEFLECTION =      .00001 IN
JET SCRUBBING NOISE CRITICAL STRESS =   5.3767E+01 PSI
NO. OF STRESS REVERSALS =   8.5209E+04
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   4.9739E+04 PSI

COMPOSITE CRITICAL STRESS =   6.3266E+01 PSI
NO. OF STRESS REVERSALS =   6.4067E+05
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   3.4448E+04 PSI
```

Figure 4-8. Output of Sample Problem - Results of Fatigue Analysis

```
***** W E I G H T - C O S T   I N P U T *****

      KINDP      LENGTH       WIDTH      DLPANL      DWPANL           A           B
          1       6.000      24.000       1.000       1.000        .500        .500

      KINDS       TINS1       TINS2       TINS3       PINS1       PINS2       PINS3
          1       0.000       0.000       0.000      -0.000      -0.000      -0.000

      NRIBS       CHORD      RADIUS      TSKIN1      TSKIN2      PSKIN1      PSKIN2
          5       2.000       6.000      -0.000        .025        .300        .300

      GBOLT      GNUTPL       GWASH       TCORN       TPOST       PPOST      ODPOST
       .400        .500        .100        .010        .020        .300        .500

     TPLATE       TENG1       TTUBE       PTUBE       LTUBE       TSEAL       PSEAL
       .010        .050        .020        .300        .600        .010        .300

     TDOUBC      TDOUBP       TBMLA       TBMSA      HBEAMA      WBEAMA         PBM
       .010        .010        .010        .010        .500       1.000        .300

***** E N D   O F   I N P U T *****
```

Figure 4-9. Output of Sample Problem - Input to Weight/Cost Analysis

THERMAL PROTECTION SYSTEM, SPACE SHUTTLE STA XXXX

CONFIGURATION PANEL TYPE 1, CORRUGATED   NOMINAL PANEL SIZE 3.0 X 2.0 FT
STRUCTURE TYPE A   NOMINAL STANDOFF LENGTH .5 IN

DESCRIP	QT	THEORETL WEIGHT	ACTUAL WEIGHT	MATL WEIGHT	STD HOURS	LABOR HOURS	LABOR RATE	OV-HD RATE	MATL $ PER LB	LABOR COST	OVERHD COST	FACTORY COST	MATERIAL COST	FABRICAT COST
PANEL	1	0.000	14.272	18.319	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CORRUGNS	1	0.000	14.272	17.014	9.8908	24.73	4.75	8.31	14.50	117.45	205.54	323.00	271.38	594.37
STRUCTURE	1	0.000	1.140	1.701	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BEAM LN A	1	0.000	.349	.425	.3381	.85	4.75	8.31	14.00	4.01	7.03	11.04	6.55	17.59
BEAM SH A	1	0.000	.217	.280	.2103	.53	4.75	8.31	14.00	2.50	4.37	6.87	4.32	11.19
CORNERS	1	0.000	.058	.088	.0628	.16	4.75	8.31	13.50	.75	1.30	2.05	1.30	3.35
POST CORN	2	0.000	.067	.383	.3111	.59	4.75	8.31	12.00	2.78	4.87	7.65	5.05	12.70
SEAL	1	0.000	.073	.112	.0505	.13	4.75	8.31	14.50	.60	1.05	1.65	1.79	3.44
FASTENERS	40	0.000	.375	.412	0.0000	0.00	0.00	0.00	172.71	0.00	0.00	0.00	60.22	60.22

TOTAL THEORETICAL WEIGHT	0.00 LB
TOTAL ACTUAL WEIGHT	15.41 LB
TOTAL MATERIAL WEIGHT	18.72 LB
TOTAL STANDARD HOURS	10.86 HR
TOTAL LABOR HOURS	26.97 HR
TOTAL LABOR COST	128.09 $
TOTAL OVER COST	224.16 $
TOTAL FACTORY COST	352.25 $
TOTAL MATERIAL COST	350.61 $
TOTAL FABRICATION COST	702.86 $
TOTAL ASSEMBLY COST	21.05 $
TOTAL MANUFACTURING COST	723.91 $
TPS COST	120.65 $/SQ FT
TPS WEIGHT	2.57 LB/SQ FT
AVERAGE MATERIAL	18.73 $/LB
AVERAGE LABOR RATE	4.75 $/HR
AVERAGE OVERHEAD RATE	8.31 $/HR
AVERAGE FACTORY RATE	13.06 $/HR
AVERAGE MFG. RATE	26.06 $/HR
AVERAGE MFG. RATE	45.60 $/LB
AVERAGE REALIZATION FACTOR	.40
ASSEMBLY REALIZATION FACTOR	.40
COMPONENT NON-OPTIMUM	0.00

SUB-ASSEMBLY COST

TASK	STD HOURS	TOTAL HOURS	LABOR RATE	OV-HR RATE	LABOR COST	OVERHD COST	ASSEMBLY COST
LOCATE	.0456	.11	5.20	1.75	.59	1.04	1.63
CLAMP	.2800	.70	5.20	1.75	3.64	6.37	10.01
DRILL	.0418	.10	5.20	1.75	.54	.95	1.49
SECURE	.0570	.14	5.20	1.75	.74	1.30	2.04
INSPECT	.0304	.08	5.20	1.75	.40	.69	1.09
DISASSY	.0960	.24	5.20	1.75	1.25	2.18	3.43
CLEAN	.0380	.09	5.20	1.75	.49	.86	1.36

Figure 4-10. Output of Sample Problem - Weight/Cost Results

```
               THERMAL PROTECTION SYSTEM - COST SUMMARY

                                                          COST(M$)

THEORETICAL FIRST UNIT COSTS - TFU    8.340

NON RECURRING COST

RD AND D                                                    50.919
TOOLING                                                     52.809
GROUND TEST HARDWARE                                        20.434
FLIGHT TEST ARTICLES                                        16.681
FLIGHT TEST S AND RP                                         5.588
                                                          --------
TOTAL NONRECURRING TPS COST                                146.431

RECURRING PRODUCTION COST

SUSTAINING ENGINEERING            -           INCLUDED IN TFU
SUSTAINING TOOLING                -           INCLUDED IN TFU
PRODUCTION ARTICLES (1)                                      8.340
TEST ARTICLE CONVERSION                                      2.502
                                                          --------
TOTAL RECURRING PRODUCTION COST                             10.843

RECURRING OPERATIONS COST

REPLENISHMENT S AND RP                                      11.109
                                                          --------
TOTAL RECURRING OPERATIONS COST                             11.109


TOTAL THERMAL PROTECTION SYS PROGRAM COSTS 168.383
```

Figure 4-11. Output of Sample Problem - Results of Program Total Cost Analysis

SECTION 5

REFERENCES

1. Whitehead, K. D., et al., Computation Techniques for Design Optimization of Thermal Protection Systems for the Space Shuttle Vehicle, Volume I, Final Report, Convair Aerospace Division of General Dynamics, GDC-DDB71-005, 30 September 1971.

2. Marks, Lionel S., Mechanical Engineers' Handbook, McGraw-Hill Book Company, New York, 1951, pp. 197-200.

3. Shanley, F. R., Strength of Materials, McGraw-Hill Book Company, New York, 1957.

APPENDIX I

PROGRAM SOURCE LISTINGS

```
      PROGRAM TPSOPT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
      DIMENSION A(20),ALPHA(99),ALT(99),AX(9,9,9),AY(9,9,9),BETA(99),
     1DIST(9),E(20,99),EAT(20,99),EDOT(20,99),EMIS(9),FCY(20,99),
     2FNET(20),FT(20),FTU(20,99),HINSD(99),MAT(9,9),MPT(9,9),MR(9,18),
     3NI(18),NR(18),PINP(99),Q(9),QCONL(9),QCONT(9),QINP(99),QNET(9),
     4RHO(9),T(20,99),TAMP(9,9),TEMP(9,9),TIME(99),TINSD(99),VFACT(9,18)
     5,VINF(99),X(9),XX(20),Y(9),ZZ(20),TALLW(9)
      DIMENSION TMAX(9)
      COMMON  A      ,AL     ,ALPHA  ,ALT    ,AME    ,AMI    ,AOFA   ,
     1AROD   ,AS     ,AX     ,AY     ,BATA   ,BE     ,BETA   ,BF     ,
     2BFL    ,BL     ,DELTA  ,DIAM   ,DIST   ,DNX    ,DNY    ,DNZ    ,
     3DST    ,E      ,EALL   ,EAT    ,EDOT   ,EMIS   ,FCY    ,FNET   ,
     4FT     ,FTU    ,F07    ,HH     ,HINS   ,HINSD  ,ICONF  ,IQINP  ,
     5ITURB  ,IWALT  ,MAT    ,MPT    ,MR     ,NCOLM  ,NCR    ,NF     ,
     6NI     ,NPSG   ,NR     ,NRSG   ,NSECT  ,NSEG   ,NTRAJ  ,PE     ,
     7PI     ,PINP   ,Q      ,QCONL  ,QCONT  ,QINP   ,QNET   ,R      ,
     8RHO    ,RHOI   ,RYE    ,RYI    ,SL     ,SLS    ,STAAT  ,STI    ,
     9STOOP  ,T      ,TAMP   ,TAU    ,TC     ,TC1    ,TEMP   ,TI     ,
     $TIME   ,TINS   ,TINSD  ,TS     ,UF     ,VFACT  ,VI     ,VINF   ,
     $WROTE  ,X      ,XEMIS  ,XX     ,Y      ,ZZ     ,NCRC   ,TALLW  ,
     $NINS   ,FACC   ,NPRT
      COMMON/SONIC1/  AE     ,AI     ,AW     ,AMACH  ,BW     ,C(4)   ,
     1D      ,DT(4)  ,DVEH   ,EP     ,HPAN   ,HC     ,HF     ,IPAD   ,
     2KFLEX  ,NENG   ,NPAN   ,QL     ,REY    ,RHOP   ,TJ     ,TT     ,
     3VJ     ,VS     ,VU     ,VV     ,WEJ    ,WER    ,IPF(4) ,XI     ,
     4XJ     ,XL     ,YP     ,IPFI   ,AIY    ,DREF   ,YCL
C
      DO 10 I=1,15161
   10 A(I)=0.
   20 CALL INPUT1
      IF (IQINP.EQ.1) QL = 0.
   30 IGO=0
      IVF=0
      IDT=0
      ISS=0
      IST=0
      ICK=1
      YINS=0.0
      DO 40 I=1,NCOLM
      DO 40 J=1,NSEG
   40 TEMP(I,J)=TAMP(I,J)
      IF (NINS.EQ.0) GO TO 60
      DO 50 J=1,NSEG
      K=MAT(1,J)
      TMAX(K)=0.0
      IF (K.EQ.NINS) YINS=YINS+Y(J)
   50 CONTINUE
   60 TAU=STAAT
      DEL=STAAT
   70 IF (WROTE.GT.DEL) GO TO 80
      DEL=DEL-WROTE
      GO TO 70
   80 IF (NCOLM.GT.1.OR.NRSG.EQ.0) GO TO 100
      DO 90 I=1,NRSG
   90 VFACT(1,I)=1.
  100 TAU=TAU+DELTA
      TEU=TAU-0.5*DELTA
      IF (NTRAJ-2) 160,140,110
  110 DO 120 I=1,NTRAJ
```

Figure I-1. Source Listing — TPSOPT

```
      IF (TEU-TIME(I)) 130,170,120
  120 CONTINUE
      I=NTRAJ
  130 IF (I-1) 140,140,150
  140 I=2
  150 FR=(TEU-TIME(I-1))/(TIME(I)-TIME(I-1))
      AL=(ALT(I)-ALT(I-1))*FR+ALT(I-1)
      VI=(VINF(I)-VINF(I-1))*FR+VINF(I-1)
      AOFA=(ALPHA(I)-ALPHA(I-1))*FR+ALPHA(I-1)
      BATA=(BETA(I)-BETA(I-1))*FR+BETA(I-1)
      HINS=(HINSD(I)-HINSD(I-1))*FR+HINSD(I-1)
      TINS=(TINSD(I)-TINSD(I-1))*FR+TINSD(I-1)
      IF (IQINP.GT.1) GO TO 180
      GO TO 210
  160 I=1
  170 AL=ALT(I)
      VI=VINF(I)
      AOFA=ALPHA(I)
      BATA=BETA(I)
      HINS=HINSD(I)
      TINS=TINSD(I)
      IF (IQINP.GT.1) GO TO 180
      GO TO 210
  180 DO 200 I=1,NCOLM
      IF (IQINP.EQ.3) GO TO 190
      Q(I)=AL*QCONL(I)
      PE=VI
      GO TO 200
  190 TEMP(I,1)=AL*QCONL(I)
      PE=VI
  200 CONTINUE
      GO TO 230
  210 CALL PRA63(AL,PI,TI,RHOI,ICK)
      IF (ICK.EQ.0) GO TO 310
      IF (IQINP.NE.1) GO TO 220
      AMI=VI/(49.01*SQRT(TI))
      QI=0.5*RHOI*VI**2
      IF (QI.LT.QL) GO TO 220
      QL=QI
      AMACH=AMI
      VU=VI
      REY=RHOI*VU*XL/(2.27E-8*TI**1.5/(TI+198.6))
  220 CALL THERMO(IGO)
      IF (IGO.EQ.1) GO TO 310
  230 CALL CONDTN(IVF)
      IF (IVF.NE.2) GO TO 240
      WRITE (6,360) DELTA
      GO TO 30
  240 IF (NINS.EQ.0) GO TO 300
      DO 250 I=1,NCOLM
      DO 250 J=1,NSEG
      K=MAT(I,J)
      IF (TEMP(I,J).GT.TMAX(K)) TMAX(K)=TEMP(I,J)
  250 CONTINUE
      DO 260 K=1,9
      IF (TMAX(K).GT.TALLW(K)) GO TO 270
  260 CONTINUE
      GO TO 300
  270 YINS=0.0
      DO 280 L=1,NSEG
```

Figure I-1. Source Listing — TPSOPT, Contd

```
      KK=MAT(1,L)
      IF (KK.NE.NINS) GO TO 280
      Y(L)=FACC*Y(L)
      YINS=YINS+Y(L)
  280 CONTINUE
      WRITE (6,390) K,K,TMAX(K),K,TALLW(K),TAU
      WRITE (6,410) YINS
      IF (YINS.GT.1.0) GO TO 290
      WRITE (6,420)
      GO TO 30
  290 WRITE (6,400)
      WRITE (6,420)
      STOP
  300 DEL=DEL+DELTA
      IF (IDT.NE.1) GO TO 320
      IDT=2
      GO TO 30
  310 IST=2
      GO TO 330
  320 IF (TAU+.01*DELTA.LT.STOOP.AND.DEL+.01*DELTA.LT.WROTE) GO TO 100
      IF (TAU+.01*DELTA.GE.STOOP) IST=2
      IF (NINS.NE.0) GO TO 330
      CALL STRESS(ISS,IST)
  330 IF (NPRT.EQ.1.AND.TAU.LT.STOOP) CALL PRINT1(ISS)
      IF (IST.EQ.2) GO TO 340
      DEL=0.
      GO TO 100
  340 IF (IGO.EQ.1) WRITE (6,370)
      IF (ICK.EQ.0) WRITE (6,380)
      CALL FATIG(NSECT,TC,TS)
      T1=YINS
      T2=0.
      T3=0.
      CALL DRVTPS(T1,T2,T3,TS,TC)
      DO 350 I=1,9
      Q(I)=0.
      QNET(I)=0.
      DO 350 J=1,9
  350 TEMP(I,J)=0.
      GO TO 20
C
C
  360 FORMAT (32H ***** DELTA HAS BEEN CHANGED TO,E10.4,10H SEC *****)
  370 FORMAT (46H ***** LOCAL VELOCITY SQUARE IS NEGATIVE *****)
  380 FORMAT (42H ***** ALTITUTE.LT.0.OR.GT.700000 FT *****)
  390 FORMAT (//56H0***** I N S U L A T I O N   S I Z I N G   N O T E **
     1***//25H TEMPERATURE OF MATERIAL ,I2,17H BECAME TOO HIGH.,/6H TMAX
     2(,I1,3H) =,F5.0,6H DEG-R,/7H TALLW(,I1,3H) =,F5.0,6H DEG-R,/7H TIM
     3E =,F5.0,4H SEC,/)
  400 FORMAT (43H THICKNESS OF THE INSULATION IS UNREALISTIC/34H PROBLEM
     1 WAS DELETED AT THIS POINT)
  410 FORMAT (44H THICKNESS OF THE INSULATION WAS CHANGED TO ,F6.4,3H FT
     1)
  420 FORMAT (34H0***** E N D   O F   N O T E *****)
      END
```

Figure I-1. Source Listing — TPSOPT, Contd

```
FUNCTION ALL(ARR,CY)
DIMENSION ARR(4)
A1(X)=(ARR(1)+ARR(2)*X+ARR(3)*X**2+ARR(4)*X**3)*1000.0
Y=ALOG10(CY)
YY=ALOG10(1.01*CY)
ALL=(A1(YY)-A1(Y))/(0.01*CY)*CY
RETURN
END
```

Figure I-2. Source Listing — ALL

```
      FUNCTION APP(SLD,CY,CYL,ARR)
      COMMON/APP1/NOAPP
      DIMENSION C(3), ARR(4)
      DATA (C(I),I=1,3)/2.631102E-02,-2.635E-02,-4.939331E-01/
      A1(X)=2./PI*ACOS(1.-PI/1.212*(1.-X))
      A2(X)=(-C(2)-SQRT(C(2)**2-4.*C(3)*(C(1)-ALOG(X))))/(2.*C(3))
      A3(X)=(ARR(1)+ARR(2)*X+ARR(3)*X**2+ARR(4)*X**3)*1000.
      PI=3.14159
      Y=CY/CYL
      IF (Y.GT.0.455.AND.Y.LT.1.0) GO TO 30
      YY=Y-0.0001
      IF (YY.GE.0.) GO TO 20
      YY=0.
      IF (A2(Y)*SLD.GT.A3(Y)) GO TO 10
      WRITE (6,50)
      NOAPP=1
      RETURN
   10 NOAPP=2
      WRITE (6,60)
      RETURN
   20 Z=(A2(Y)-A2(YY))*10000.
      APP=Z*SLD/CYL*CY
      RETURN
   30 YY=Y+0.0001
      IF (YY.LE.1.) GO TO 40
      YY=1.
      FACT=YY-Y
      Z=(A1(YY)-A1(Y))/FACT
      APP=Z*SLD/CYL*CY
      RETURN
   40 Z=(A1(YY)-A1(Y))*10000.
      APP=Z*SLD/CYL*CY
      RETURN
C
   50 FORMAT (///50H ***** S O N I C   F A T I G U E   N O T E *****/5
     10H  THE NUMBER OF STRESS REVERSALS IS SO LOW THAT  /50H  FATIGUE
     2IS NOT A FACTOR FOR THIS CONFIGURATION  /50H  AND ALLOWABLE S-N CU
     3RVE.  THE ACOUSTIC FATIGUE  /50H  ANALYSIS FOR THIS NOISE SOURCE I
     4S OMITTED.      /7X,35H***** E N D   O F   N O T E *****//)
   60 FORMAT (47H0APPLIED S-N CURVE EXCEEDS ALLOWABLE S-N CURVE.)
      END
```

Figure I-3. Source Listing — APP

```
      FUNCTION BANDW(F)
C
C                    THIS SUBROUTINE COMPUTES BANDWIDTH AS A FUNCTION
C                    OF FREQUENCY
      DIMENSION FTB(13),BWTB(13)
      DATA FTB/  2.,     4.,     8.,     16.,
     1     31.5     ,63.0    ,125.    ,250.    ,500.    ,
     2     1000.    ,2000.   ,4000.   ,8000. /
      DATA BWTB/1.35, 2.75,  5.5,  11.,
     1     22.5     ,45.0    ,90.0    ,180.    ,355.    ,
     2     700.     ,1400.   ,2800.   ,5600.            /
      IF (F.GE..65.AND.F.LE.10800.) GO TO 10
      WRITE (6,30) F
      IF (F.LT.0.65) BANDW=1.35
      IF (F.GT.10800.) BANDW=5600.
      RETURN
   10 I=0
   20 I=I+1
      IF (F.GT.(FTB(I)+BWTB(I)/2.)) GO TO 20
      BANDW=BWTB(I)
      RETURN
C
   30 FORMAT (19H0FREQ. ARG. ERROR =E12.4)
      END
```

Figure I-4. Source Listing — BANDW

```
 BLOCK DATA
 COMMON/WTCOST/
1KLIC       ,N           ,ACWT      ,KT        ,ITL ,LEN, WID, LTUBER
2,MAWT,KK,AOP(7,7),KMUV(100,3),KSETUP(100,21),KRUN(100,21)
3,KCC(5,21),TIME(7),TMAT(3),DIAMA(6),WTNUT(6),TBTABL(6)
4,KCOSWT(100,3)
 COMMON/ALPHAN/
1ANAM1(22) ,ANAM2(22),ANAM3(22)
 REAL KSETUP,KRUN,KCC,MUV,MAWT,KMUV
 REAL KCOSWT
 REAL LARATE,LABHR,LACOST,MFCOS,MATCOS
 DATA
1ANAM1/4HINSU,4H INS,4H INS,4H INS,4HPANE,4H COR,4H EDG,4H HON,
24H RIB,4H SKI,4HSTRU,4H BEA,4H BEA,4H COR,4H INS,4H POS,4H SEA,
34H INS,4H BEA,4H BEA,4H POS,4H FAS/
 DATA
1ANAM2/4HLATI,4HUL 1,4HUL 2,4HUL 3,4HL   ,4HRUGN,4HES  ,4HEYCO,
24HS   ,4HN   ,4HCTUR,4HM LN,4HM SH,4HNERS,4HERTS,4HT CO,4HL   ,
34HULAT,4HM LN,4HM SH,4HT CE,4HTENE/
 DATA
1ANAM3/2HON,2H  ,2H  ,2H  ,2H  ,2HS ,2H  ,2HMB,2H  ,2H  ,2HE ,
22H A,2H A,2H  ,2H  ,2HRN,2H  ,2HOR,2H C,2H C,2HNT,2HRS/
 DATA
1TBTABL/.036,.045,.125,.150,.200,.250/,
2DIAMA/.125,.156,.1875,.250,.3125,.375/,
3WTNUT/.0006,.00076,.00088,.00164,.00425,.00672/,
4TIME/.035,.0008,.001,.0015,.012,.0012,.52/,
5TMAT/1.0,3.0,3.0/
 DATA
1KMUV/300*1.1/
 DATA
1KSETUP(1,1),KSETUP(2,1),KSETUP(3,1),KSETUP(4,1),KSETUP(5,1),
2KSETUP(11,1),KSETUP(12,1),KSETUP(13,1),KSETUP(21,1),KSETUP(51,1)/
3.0005,.0006,.0007,.0008,.0010,.0010,.0020,.0024,.0016,.0050/
4,KSETUP(61,1),KSETUP(71,1),KSETUP(91,1),KSETUP(92,1),KSETUP(93,1)/
5.0001,.0001,.0008,.0008,.0008/
 DATA
1KSETUP(11,4),KSETUP(12,4),KSETUP(13,4),KSETUP(21,4),KSETUP(51,4)/
2.0100,.0110,.0120,.0100,.0200/
 DATA
1KSETUP(1,7),KSETUP(3,7),KSETUP(4,7),KSETUP(5,7)/
2.0012,.0016,.0018,.0020/
 DATA
1KSETUP(1,10),KSETUP(2,10),KSETUP(3,10),KSETUP(4,10),KSETUP(5,10),
2KSETUP(11,10),KSETUP(12,10),KSETUP(13,10),KSETUP(21,10)/
3.0020,.0025,.0030,.0035,.0040,.0050,.0070,.0090,.0050/
 DATA
1KSETUP(1,13),KSETUP(2,13),KSETUP(3,13),KSETUP(4,13),KSETUP(5,13)/
2.0010,.0010,.0010,.0010,.0010/
 DATA
1KSETUP(1,16),KSETUP(2,16),KSETUP(3,16),KSETUP(4,16),KSETUP(5,16),
2KSETUP(11,16),KSETUP(12,16),KSETUP(13,16),KSETUP(21,16)/
3.0012,.0014,.0016,.0018,.0020,.0040,.0060,.0080,.0040/
 DATA
1KSETUP(1,19),KSETUP(2,19),KSETUP(3,19),KSETUP(4,19),KSETUP(5,19),
2KSETUP(11,19),KSETUP(12,19),KSETUP(13,19),KSETUP(21,19),
3KSETUP(51,19)/
4.0008,.0008,.0009,.0009,.0010,.0014,.0016,.0018,.0014,.0020/
 DATA
1KRUN(1,1),KRUN(2,1),KRUN(3,1),KRUN(4,1),KRUN(5,1),KRUN(11,1),
```

Figure I-5. Source Listing — BLOCK DATA

```
2KRUN(12,1),KRUN(13,1),KRUN(21,1),KRUN(51,1)/
3.0050,.0060,.0070,.0080,.0100,.0160,.0200,.0240,.0160,.0300/
4,KRUN(61,1),KRUN(71,1),KRUN(91,1),KRUN(92,1),KRUN(93,1)/
5.0010,.0010,.0080,.0080,.0080/
 DATA
1KRUN(11,4),KRUN(12,4),KRUN(13,4),KRUN(21,4),KRUN(51,4)/
2.1000,.1100,.1200,.1000,.2000/
 DATA
1KRUN(1,7),KRUN(3,7),KRUN(4,7),KRUN(5,7)/
2.0120,.0160,.0180,.0200/
 DATA
1KRUN(1,10),KRUN(2,10),KRUN(3,10),KRUN(4,10),KRUN(5,10),
2KRUN(11,10),KRUN(12,10),KRUN(13,10),KRUN(21,10)/
3.0200,.0250,.0300,.0350,.0400,.0500,.0700,.0900,.0500/
 DATA
1KRUN(1,13),KRUN(2,13),KRUN(3,13),KRUN(4,13),KRUN(5,13)/
2.0100,.0100,.0100,.0100,.0100/
 DATA
1KRUN(1,16),KRUN(2,16),KRUN(3,16),KRUN(4,16),KRUN(5,16),
2KRUN(11,16),KRUN(12,16),KRUN(13,16),KRUN(21,16)/
3.0120,.0140,.0160,.0180,.0200,.0400,.0600,.0800,.0400/
 DATA
1KRUN(1,19),KRUN(2,19),KRUN(3,19),KRUN(4,19),KRUN(5,19),
2KRUN(11,19),KRUN(12,19),KRUN(13,19),KRUN(21,19),KRUN(51,19)/
3.0080,.0080,.0090,.0090,.0100,.0140,.0160,.0180,.0140,.0200/
 DATA
1KCOSWT(1,1),KCOSWT(2,1),KCOSWT(3,1),KCOSWT(4,1),KCOSWT(5,1),
2KCOSWT(11,1),KCOSWT(12,1),KCOSWT(13,1),KCOSWT(21,1),KCOSWT(51,1),
3KCOSWT(81,1)/
415.00,14.50,14.00,13.50,13.00,12.00,12.50,14.00,10.50,65.00,
5132.71/
6,KCOSWT(61,1),KCOSWT(71,1),KCOSWT(91,1),KCOSWT(92,1),KCOSWT(93,1)/
7[illegible],50.00,50.00,50.00/
C     REAL TABLE
C     RATE TABLE
C     OVERHEAD RATE TABLE
 DATA
1KCC(5,1),KCC(5,2),KCC(5,3)/.4,4.75,1.75/,
2KCC(2,4),KCC(2,5),KCC(2,6)/.4,4.75,1.75/,
3KCC(2,7),KCC(2,8),KCC(2,9)/.4,4.75,1.75/,
4KCC(1,10),KCC(1,11),KCC(1,12)/.4,4.75,1.75/,
5KCC(1,13),KCC(1,14),KCC(1,15)/.4,4.75,1.75/,
6KCC(1,16),KCC(1,17),KCC(1,18)/.4,4.75,1.75/,
7KCC(3,19),KCC(3,20),KCC(3,21)/.4,4.75,1.75/,
8KCC(6,1),KCC(6,2),KCC(6,3)/.4,5.20,1.75/,
9KCC(7,1),KCC(7,2),KCC(7,3)/.4,5.20,1.75/
 END
```

Figure I-5. Source Listing — BLOCK DATA, Contd

```
      SUBROUTINE BUCKNG(E,F7,FCR,FCY,FTU,NCR)
      DE=E*(1.-1./(1.+.4286*(FCR/F7)**(NCR-1)))
      IF (.001*E.GE.ABS(DE)) GO TO 20
      ETA0=0.7
      ETAA=F7/FCR
   10 ETA1=ETAA*((1./ETA0-1.)*2.333)**(1./(FLOAT(NCR)-1.))
      DETA=ETA1-ETA0
      IF (ETA1.GT.1.) ETA1=1.
      IF (.01*ETA0.GE.ABS(DETA)) GO TO 30
      ETA0=0.5*(ETA0+ETA1)
      GO TO 10
   20 ETA1=1.
   30 FCR=FCR*ETA1
      IF (1.1*FCY.GE.FCR) GO TO 40
      FCR=1.1*FCY
   40 IF (FTU.GE.FCR) GO TO 50
      FCR=FTU
   50 RETURN
      END
```

Figure I-6. Source Listing — BUCKNG

```
      SUBROUTINE CONDTN(IVF)
C
      DIMENSION A1(9,9),A2(9,9),A3(9,9),NRA(18),QN(4),Q2(9),VF(9,18),
     1DX(9),DY(9,9),A4(9,9)
      DIMENSION A(20),ALPHA(99),ALT(99),AX(9,9,9),AY(9,9,9),BETA(99),
     1DIST(9),E(20,99),EAT(20,99),EDOT(20,99),EMIS(9),FCY(20,99),
     2FNET(20),FT(20),FTU(20,99),HINSD(99),MAT(9,9),MPT(9,9),MR(9,18),
     3NI(18),NR(18),PINP(99),Q(9),QCONL(9),QCONT(9),QINP(99),QNET(9),
     4RHO(9),T(20,99),TAMP(9,9),TEMP(9,9),TIME(99),TINSD(99),VFACT(9,18)
     5,VINF(99),X(9),XX(20),Y(9),ZZ(20),TALLW(9)
      COMMON  A        ,AL       ,ALPHA    ,ALT      ,AME      ,AMI      ,AOFA     ,
     1AROD    ,AS       ,AX       ,AY       ,BATA     ,BE       ,BETA     ,BF       ,
     2BFL     ,BL       ,DELTA    ,DIAM     ,DIST     ,DNX      ,DNY      ,DNZ      ,
     3DST     ,E        ,EALL     ,EAT      ,EDOT     ,EMIS     ,FCY      ,FNET     ,
     4FT      ,FTU      ,F07      ,HH       ,HINS     ,HINSD    ,ICONF    ,IQINP    ,
     5ITURB   ,IWALT    ,MAT      ,MPT      ,MR       ,NCOLM    ,NCR      ,NF       ,
     6NI      ,NPSG     ,NR       ,NRSG     ,NSECT    ,NSEG     ,NTRAJ    ,PE       ,
     7PI      ,PINP     ,Q        ,QCONL    ,QCONT    ,QINP     ,QNET     ,R        ,
     8RHO     ,RHOI     ,RYE      ,RYI      ,SL       ,SLS      ,STAAT    ,STI      ,
     9STOOP   ,T        ,TAMP     ,TAU      ,TC       ,TC1      ,TEMP     ,TI       ,
     $TIME    ,TINS     ,TINSD    ,TS       ,UF       ,VFACT    ,VI       ,VINF     ,
     $WROTE   ,X        ,XEMIS    ,XX       ,Y        ,ZZ       ,NCRC     ,TALLW    ,
     $NINS    ,FACC     ,NPRT
C
      I1=0
      A1S=0.
      QSS=0.
      IF (NRSG.EQ.0) GO TO 20
      L=0
      DO 10 I=1,NRSG
   10 NRA(I)=NR(I)
   20 X2=0.
      DO 70 I=1,NCOLM
      IF (NCRC.LT.2) GO TO 30
      X1=X2
      X2=XX(I)**2
      DX(I)=3.1416*(X2-X1)
      GO TO 40
   30 DX(I)=X(I)
   40 IF (IQINP.EQ.3) GO TO 50
      QNET(I)=Q(I)-0.476E-12*XEMIS*TEMP(I,1)**4
   50 DO 70 J=1,NSEG
      K=MAT(I,J)
      K=IABS(K)
      IF (K.EQ.0) GO TO 70
      CP=TRPLAT(AY,AX,TEMP(I,J),K,1,MPT(K,1))
      EK=1.8E3/TRPLAT(AY,AX,TEMP(I,J),K,2,MPT(K,2))
      A1(I,J)=CP*RHO(K)*DX(I)*Y(J)
      XY=DX(I)/Y(J)
      A3(I,J)=EK/XY
      IF (NCRC.EQ.2) GO TO 60
      DY(I,J)=Y(J)
      A2(I,J)=EK*XY
      GO TO 70
   60 A2(I,J)=.3183*EK*ALOG(XX(I)/(XX(I)-.5*X(I)))/Y(J)
      DY(I,J)=6.2832*XX(I)*Y(J)
      IF (I.EQ.1) GO TO 70
      A4(I,J)=.3183*EK*ALOG((XX(I)-.5*X(I))/XX(I-1))/Y(J)
   70 CONTINUE
      DO 370 J=1,NSEG
```

Figure I-7. Source Listing — CONDTN

```
      DO 370 I=1,NCOLM
      IF (MAT(I,J).EQ.0) GO TO 370
      IF (IQINP.EQ.3.AND.J.EQ.1) GO TO 190
      QS=0.
      DO 330 K=1,4
      GO TO (80,90,100,110), K
   80 IF (I.EQ.1) GO TO 120
      IF (MAT(I-1,J)) 120,210,140
   90 IF (I.EQ.NCOLM.OR.MAT(I,J).LT.0.) GO TO 120
      IF (MAT(I+1,J)) 160,210,160
  100 IF (J.EQ.1) GO TO 130
      IF (NCOLM.EQ.1) GO TO 150
      IF (MAT(I,J-1)) 150,210,150
  110 IF (J.EQ.NSEG) GO TO 320
      IF (MAT(I,J+1)) 190,200,190
  120 QN(K)=0.
      GO TO 330
  130 QN(3)=QNET(I)*DX(I)
      GO TO 330
  140 QN(1)=-QN(2)
      GO TO 330
  150 QN(3)=-Q2(1)
      GO TO 330
  160 IF (NCRC.LE.1) GO TO 170
      SA=A2(I,J)+A4(I+1,J)
      GO TO 180
  170 SA=A2(I,J)+A2(I+1,J)
  180 QN(2)=(TEMP(I+1,J)-TEMP(I,J))/SA
      GO TO 330
  190 QN(4)=(TEMP(I,J+1)-TEMP(I,J))/(A3(I,J+1)+A3(I,J))
      Q2(I)=QN(4)
      IF (IQINP.EQ.3.AND.J.EQ.1) GO TO 370
      GO TO 330
  200 QN(K)=0.
      IF (NCOLM.GT.1) GO TO 210
      IJ=1
      M=1
      L=L+1
      N=J+2
      GO TO 240
  210 QN(K)=0.
      IF (NRSG.EQ.0) GO TO 330
      NRP=10*I+J
      DO 220 L=1,NRSG
      IF (NRP.EQ.NRA(L)) GO TO 230
  220 CONTINUE
      GO TO 330
  230 NRA(L)=0
      IJ=NI(L)
  240 DO 310 II=1,IJ
      IF (NCOLM.EQ.1) GO TO 250
      M=MR(II,L)/10
      N=MR(II,L)-10*M
  250 IF (IVF.EQ.1) GO TO 300
      IF (K.EQ.1.OR.K.EQ.2) GO TO 260
      RL=DX(I)
      GO TO 270
  260 RL=DY(I,J)
  270 M1=MAT(I,J)
      E1=EMIS(M1)
```

Figure I-7. Source Listing — CONDTN, Contd

```
      M2=MAT(M,N)
      IF (M2.EQ.0) GO TO 280
      E2=EMIS(M2)
      E12=E1*E2/(1.-(1.-E1)*(1.-E2))
      GO TO 290
  280 E12=E1
  290 VF(II,L)=0.476E-12*E12*RL*VFACT(II,L)
      IF (L.EQ.NRSEG.AND.II.EQ.IJ) IVF=1
  300 QR=VF(II,L)*(TEMP(M,N)**4-TEMP(I,J)**4)
  310 QN(K)=QN(K)+QR
      GO TO 330
  320 QN(4)=HINS*DX(I)*(TINS-TEMP(I,J))
      IF (HINS.GE.1.E9) QN(4)=-QS
  330 QS=QS+QN(K)
      QSS=QSS+QS
      A1S=A1S+A1(I,J)
      I1=I1+1
      IF (MAT(I,J).LT.0.) GO TO 370
      DET=DELTA*QSS/A1S
      IF (ABS(DET).LT.500.) GO TO 340
      WRITE (6,390) I,J
      IVF=2
      DELTA=0.5*DELTA
      IF (DELTA.GE.0.1) GO TO 380
      WRITE (6,400)
      STOP
  340 TEMP(I,J)=TEMP(I,J)+DET
      IF (I1.LE.1) GO TO 360
      DO 350 I2=2,I1
      I3=I-I2+2
  350 TEMP(I3-1,J)=TEMP(I3,J)
  360 I1=0
      A1S=0.
      QSS=0.
  370 CONTINUE
  380 RETURN
  390 FORMAT (1H0,14HSEGMENT NUMBER,I3,I1,43HTEMPERATURE CHANGE IS GREAT
     1ER THEN 500 DEG.)
  400 FORMAT (35H PROBLEM WAS DELETED AT THIS POINT.)
      END
```

Figure I-7. Source Listing — CONDTN, Contd

```
      SUBROUTINE COST
      COMMON/WTA/
     1A        ,B        ,CHORD    ,E1RIB    ,E2RIB    ,E3RIB    ,
     2HBEAMA   ,HFNG1    ,HFNG2    ,HRIB     ,HRING    ,IDFNG1   ,
     3IDFNG2   ,KINDP    ,KINDS    ,LENGTH   ,DLPANL   ,LTUBE    ,
     4NRIBS    ,ODPOSR   ,ODPOST   ,ODRING   ,RADIUS   ,TBMLA    ,
     5TBMLC    ,TBMSA    ,TBMSC    ,TCORE    ,TCORN    ,TDOUBC   ,
     6TDOUBP   ,TEDGE    ,TFNG1    ,TINS1    ,TINS2    ,TINS3    ,
     7TPLATE   ,TPOST    ,T1RIB    ,T2RIB    ,TWRIB    ,TRIBL    ,
     8TRIBS    ,TRING1   ,TRING2   ,TSEAL    ,TSKIN1   ,TSKIN2   ,
     9TTUBE    ,WIDTH    ,WBEAMA   ,WBMLC    ,WBMSC    ,DWPANL   ,
     $WPOST    ,WRIBL    ,WRIBS    ,PBM      ,PCORE    ,PEDGE    ,
     $PINS1    ,PINS2    ,PINS3    ,PPOST    ,PRIB     ,PSEAL    ,
     $PSKIN1   ,PSKIN2   ,PTUBE    ,GBOLT    ,GCLAMP   ,GINSRT   ,
     $GINSUL   ,GNUTPL   ,GWASH
      COMMON/WTCOST/
     1KLIC     ,N        ,ACWT     ,KT       ,ITL ,LEN, WID, LTUBER
     2,MAWT,KK,AOP(7,7),KMUV(100,3),KSETUP(100,21),KRUN(100,21)
     3,KCC(5,21),TIME(7),TMAT(3),DIAMA(6),WTNUT(6),TBTABL(6)
     4,KCOSWT(100,3)
      COMMON/ZERO/
     1 TOPWT,TACWT,TMAWT,TTSHR,TTLBHR,TTLACO,TTVCOS,TTFCOS,TTMCOS,
     2TASYCO,LABHR,       LACOST,VCOST,TSTDHR,TLACOS,TVCOST,TFCOST
      COMMON/COMTOT/ CF,K1,STPS,AT,K2,BT,TDH,C,EGTH,NFTA,EFTS,NPA,ETA,
     1EFA,NFLTS,TUNWT
      REAL K1,K2
      REAL KSETUP,KRUN,KCC,MUV,MAWT,KMUV
      REAL KCOSWT
      COMMON/ALPHAN/
     1ANAM1(22) ,ANAM2(22),ANAM3(22)
      REAL LBMLA, LBMSA, LPANL, LPOST, LSEAL, LEN
      REAL LARATE,LABHR,LACOST,MFCOS,MATCOS
      JJ=1
      SHPSET=1.
      OPWT=0
      KOP=0
      NOP=7
      COSWT=KCOSWT(KK,JJ)
      MUV=KMUV(KK,JJ)
      MATCOS=MAWT*MUV*COSWT
      KOP=KOP+1
      KS=JJ
      KR=JJ
      KF=1
      KL=2
      KV=3
   10 IF (KOP.GT.NOP) GO TO 30
      SETUP=ACWT*KSETUP(KK,KS)
      RUNTM=ACWT*KRUN(KK,KR)
      STDHR=(SETUP+(RUNTM*KT*SHPSET))*10.
      DO 20 KC=1,5
      REFCT=KCC(KC,KF)
      IF (REFCT.EQ.0.) GO TO 20
      LARATE=KCC(KC,KL)
      VRATE=KCC(KC,KV)
      LABHR=LABHR+(STDHR/REFCT)
      LACOST=LACOST+(LABHR*LARATE)
      VCOST=VCOST+(LARATE*VRATE)*LABHR
   20 CONTINUE
      FCOST=LACOST+VCOST
```

Figure I-8. Source Listing — COST

```
      MFCOS=FCOST+MATCOS
      TSTDHR=TSTDHR+STDHR
      TLBHR=TLBHR+LABHR
      TLACOS=TLACOS+LACOST
      TVCOST=TVCOST+VCOST
      TFCOST=TFCOST+FCOST
      KS=KS+3
      KR=KR+3
      KF=KF+3
      KL=KL+3
      KV=KV+3
      KOP=KOP+1
      LABHR=0
      LACOST=0
      VCOST=0
      GO TO 10
   30 IF (TLBHR.EQ.0) GO TO 40
      AVERA=TLACOS/TLBHR
      AVERF=TSTDHR/TLBHR
      TVRATE=TVCOST/TLBHR
      GO TO 50
   40 AVERA=0.
      AVERF=0.
      TVRATE=0.
   50 CONTINUE
      TMFCOS=TFCOST+MATCOS
      IF (ITL.GT.0) GO TO 60
      TACWT=0
      WRITE (6,120)
      WRITE (6,130)
      WRITE (6,200)
      WRITE (6,200)
      IF (KINDP.EQ.1) WRITE (6,140) LEN,WID
      IF (KINDP.EQ.2) WRITE (6,150) LEN,WID
      IF (KINDP.EQ.3) WRITE (6,160) LEN,WID
      IF (KINDS.EQ.1) WRITE (6,170) LTUBER
      IF (KINDS.EQ.2) WRITE (6,180) LTUBER
      IF (KINDS.EQ.3) WRITE (6,190) LTUBER
      WRITE (6,200)
      WRITE (6,210)
      WRITE (6,220)
   60 CONTINUE
      IF (KLIC.EQ.0) WRITE (6,200)
      IF (KLIC.EQ.10) GO TO 70
      IF (KLIC.GT.0) TACWT=TACWT+ACWT
      IF (KLIC.GT.0) TMAWT=TMAWT+MAWT
      WRITE (6,230) ANAM1(N),ANAM2(N),ANAM3(N),KT,OPWT,ACWT,MAWT,TSTDHR,
     1TLBHR,AVERA,TVRATE,COSWT,TLACOS,TVCOST,TFCOST,MATCOS,TMFCOS
C     SUMMARY TOTALS AT BOTTOM OF PAGE
      TOPWT=TOPWT+OPWT
      TTSHR=TTSHR+TSTDHR
      TTLBHR=TTLBHR+TLBHR
      TTLACO=TTLACO+TLACOS
      TTVCOS=TTVCOS+TVCOST
      TTFCOS=TTFCOS+TFCOST
      TTMCOS=TTMCOS+MATCOS
      LABHR=0
      LACOST=0
      VCOST=0
      TSTDHR=0
```

Figure I-8. Source Listing — COST, Contd

```
      TLBHR=0
      TLACOS=0
      TVCOST=0
      TFCOST=0
      TMFCOS=0
      RETURN
   70 CONTINUE
      WRITE (6,200)
      WRITE (6,200)
      DO 80 I=1,7
      AOP(I,2)=AOP(I,1)/KCC(6,1)
      AOP(I,3)=KCC(6,2)
      AOP(I,4)=KCC(6,3)
      AOP(I,5)=AOP(I,2)*AOP(I,3)
      AOP(I,6)=AOP(I,3)*AOP(I,4)*AOP(I,2)
      AOP(I,7)=AOP(I,5)+AOP(I,6)
   80 CONTINUE
      DO 90 I=1,7
      TASYCO=TASYCO+AOP(I,7)
   90 CONTINUE
      TTMFCO=TTFCOS+TTMCOS
      TMUFAC=TASYCO+TTMFCO
      TTMFRT=TTMFCO/TACWT
      CONOP=0
      IF (TTLBHR.EQ.0) GO TO 100
      TTRATE=TTFCOS/TTLBHR
      TMRATE=TTMFCO/TTLBHR
      TTCOS=TTMCOS/TMAWT
      TAVRA=TTLACO/TTLBHR
      TTVRA=TTVCOS/TTLBHR
      TAVFC=TTSHR/TTLBHR
      GO TO 110
  100 TTCOS=COSWT
      TAVRA=0
      TTVRA=0
      TAVFC=0
  110 CONTINUE
      TUNITC=TMUFAC/(LEN*WID)
      TUNWT=TACWT/(LEN*WID)
      REL=.4
      WRITE (6,240) TOPWT
      WRITE (6,250) TACWT
      WRITE (6,260) TMAWT
      WRITE (6,270) TTSHR
      WRITE (6,280) TTLBHR
      WRITE (6,290) TTLACO
      WRITE (6,300) TTVCOS
      WRITE (6,310) TTFCOS
      WRITE (6,320) TTMCOS
      WRITE (6,330) TTMFCO
      WRITE (6,340) TASYCO
      WRITE (6,350) TMUFAC
      WRITE (6,470)
      WRITE (6,360) TUNITC
      WRITE (6,370) TUNWT
      WRITE (6,480)
      WRITE (6,380) TTCOS
      WRITE (6,490)
      WRITE (6,390) TAVRA
      WRITE (6,400) TTVRA
```

Figure I-8. Source Listing — COST, Contd

```
      WRITE (6,500) (AOP(1,J),J=1,7)                                    CST 181
      WRITE (6,410) TTRATE                                              CST 182
      WRITE (6,510) (AOP(2,J),J=1,7)                                    CST 183
      WRITE (6,420) TMRATE                                              CST 184
      WRITE (6,520) (AOP(3,J),J=1,7)                                    CST 185
      WRITE (6,430) TTMFRT                                              CST 186
      WRITE (6,530) (AOP(4,J),J=1,7)                                    CST 187
      WRITE (6,440) TAVFC                                               CST 188
      WRITE (6,540) (AOP(5,J),J=1,7)                                    CST 189
      WRITE (6,450) REL                                                 CST 190
      WRITE (6,550) (AOP(6,J),J=1,7)                                    CST 191
      WRITE (6,460) CONOP                                               CST 192
      WRITE (6,560) (AOP(7,J),J=1,7)                                    CST 193
  120 FORMAT (1H1)                                                      CST 194
  130 FORMAT (36X,49HTHERMAL PROTECTION SYSTEM, SPACE SHUTTLE STA XXXX) CST 195
  140 FORMAT (20X,60HCONFIGURATION PANEL TYPE 1, CORRUGATED   NOMINAL PACST 196
     1NEL SIZE ,F4.1,3H X ,F4.1,3H FT)                                  CST 197
  150 FORMAT (20X,60HCONFIGURATION PANEL TYPE 2, HONEYCOMB    NOMINAL PACST 198
     1NEL SIZE ,F4.1,3H X ,F4.1,3H FT)                                  CST 199
  160 FORMAT (20X,60HCONFIGURATION PANEL TYPE 3, RIBED        NOMINAL PACST 200
     1NEL SIZE ,F4.1,3H X ,F4.1,3H FT)                                  CST 201
  170 FORMAT (20X,65H                 STRUCTURE TYPE A        NOMINAL STCST 202
     1ANDOFF LENGTH ,F4.1,3H IN)                                        CST 203
  180 FORMAT (20X,65H                 STRUCTURE TYPE B        NOMINAL STCST 204
     1ANDOFF LENGTH ,F4.1,3H IN)                                        CST 205
  190 FORMAT (20X,65H                 STRUCTURE TYPE C        NOMINAL STCST 206
     1ANDOFF LENGTH ,F4.1,3H IN)                                        CST 207
  200 FORMAT (1X,/)                                                     CST 208
  210 FORMAT (1X,128H                        THEORETL  ACTUAL    MATL     STCST 209
     1D   LABOR LABOR  OV-HD    MATL  $   LABOR   OVERHD  FACTORY MATERICST 210
     2AL FABRICAT)                                                      CST 211
  220 FORMAT (1X,126H   DESCRIP    QT   WEIGHT   WEIGHT   WEIGHT   HOUCST 212
     1RS  HOURS  RATE  RATE      PER LB    COST     COST     COST    COSTCST 213
     2    COST)                                                         CST 214
  230 FORMAT (1X,2X,1X,A4,A4,A2,I5,F7.3,F9.3,F10.3,F10.4,F8.2,F6.2,F7.2,CST 215
     1F10.2,5F9.2)                                                      CST 216
  240 FORMAT (1X,27HTOTAL THEORETICAL WEIGHT   F12.2,3H LB)             CST 217
  250 FORMAT (1X,27HTOTAL ACTUAL WEIGHT        F12.2,3H LB)             CST 218
  260 FORMAT (1X,27HTOTAL MATERIAL WEIGHT      F12.2,3H LB)             CST 219
  270 FORMAT (1X,27HTOTAL STANDARD HOURS       F12.2,3H HR)             CST 220
  280 FORMAT (1X,27HTOTAL LABOR HOURS          F12.2,3H HR)             CST 221
  290 FORMAT (1X,27HTOTAL LABOR COST           F12.2,2H $)              CST 222
  300 FORMAT (1X,27HTOTAL OVER COST            F12.2,2H $)              CST 223
  310 FORMAT (1X,27HTOTAL FACTORY COST         F12.2,2H $)              CST 224
  320 FORMAT (1X,27HTOTAL MATERIAL COST        F12.2,2H $)              CST 225
  330 FORMAT (1X,27HTOTAL FABRICATION COST     F12.2,2H $)              CST 226
  340 FORMAT (1X,27HTOTAL ASSEMBLY COST        F12.2,2H $)              CST 227
  350 FORMAT (1X,27HTOTAL MANUFACTURING COST   F12.2,2H $)              CST 228
  360 FORMAT (1X,27HTPS COST                   F12.2,8H $/SQ FT)        CST 229
  370 FORMAT (1X,27HTPS WEIGHT                 F12.2,9H LB/SQ FT)       CST 230
  380 FORMAT (1X,27HAVERAGE MATERIAL           F12.2,11H $/LB      )    CST 231
  390 FORMAT (1X,27HAVERAGE LABOR RATE         F12.2,11H $/HR      )    CST 232
  400 FORMAT (1X,27HAVERAGE OVERHEAD RATE      F12.2,11H $/HR      )    CST 233
  410 FORMAT (1X,27HAVERAGE FACTORY RATE       F12.2,11H $/HR      )    CST 234
  420 FORMAT (1X,27HAVERAGE MFG. RATE          F12.2,11H $/HR      )    CST 235
  430 FORMAT (1X,27HAVERAGE MFG. RATE          F12.2,11H $/LB      )    CST 236
  440 FORMAT (1X,27HAVERAGE REALIZATION FACTOR F12.2)                   CST 237
  450 FORMAT (1X,27HASSEMBLY REALIZATION FACTORF12.2)                   CST 238
  460 FORMAT (1X,27HCOMPONENT NON-OPTIMUM      F12.2)                   CST 239
  470 FORMAT (1H+,87X,17HSUB-ASSEMBLY COST)                             CST 240
```

Figure I-8. Source Listing — COST, Contd

```
480 FORMAT (1H+,76X,54HSTD      TOTAL  LABOR OV-HR   LABOR   OVERHD   ACST 241
   1SSEMBLY)                                                          CST 242
490 FORMAT (1H+,65X,63HTASK       HOURS     HOURS    RATE  RATE    COST CST 243
   1  COST        COST)                                               CST 244
500 FORMAT (1H+,62X,10HLOCATE    F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 245
510 FORMAT (1H+,62X,10HCLAMP     F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 246
520 FORMAT (1H+,62X,10HDRILL     F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 247
530 FORMAT (1H+,62X,10HSECURE    F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 248
540 FORMAT (1H+,62X,10HINSPECT   F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 249
550 FORMAT (1H+,62X,10HDISASSY   F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 250
560 FORMAT (1H+,62X,10HCLEAN     F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 251
    RETURN                                                            CST 252
    END                                                               CST 253-
```

Figure I-8. Source Listing — COST, Contd

```
      SUBROUTINE COSTOT
      COMMON/COMTOT/ CF,K1,STPS,AT,K2,BT,TDH,C,EGTH,NFTA,EFTS,NPA,ETA,
     1EFA,NFLTS,TUNWT
      REAL K1,K2
      WTPS=STPS*TUNWT
      TENM6=1.E-6
      TFU=(CF*K1*WTPS**AT)
      EDD=(K2*WTPS**BT)
      THLB=306.*WTPS**(C)
      TOOL=(TDH*TENM6*THLB*WTPS)
      GTH=EGTH*TFU
      FTA=NFTA*TFU
      FTSRP=EFTS*TFU
      TNTPSC=EDD+TOOL+GTH+FTA+FTSRP
      PA=NPA*TFU
      TAC=ETA*TFU
      TRPC=PA+TAC
      RSRP=EFA*NFLTS*TFU
      TROC=RSRP
      TTPSC=TNTPSC+TRPC+TROC
      WRITE (6,10)
      WRITE (6,20)
      WRITE (6,30)
      WRITE (6,40) TFU
      WRITE (6,50)
      WRITE (6,60) EDD
      WRITE (6,70) TOOL
      WRITE (6,80) GTH
      WRITE (6,90) FTA
      WRITE (6,100) FTSRP
      WRITE (6,110)
      WRITE (6,120) TNTPSC
      WRITE (6,130)
      WRITE (6,140)
      WRITE (6,150)
      WRITE (6,160) PA
      WRITE (6,170) TAC
      WRITE (6,110)
      WRITE (6,180) TRPC
      WRITE (6,190)
      WRITE (6,200) RSRP
      WRITE (6,110)
      WRITE (6,210) TROC
      WRITE (6,220) TTPSC
   10 FORMAT (1H1)
   20 FORMAT (10X,44H    THERMAL PROTECTION SYSTEM - COST SUMMARY//)
   30 FORMAT (52X,8HCOST(M$)//)
   40 FORMAT (10X,34HTHEORETICAL FIRST UNIT COSTS - TFU,F8.3,//)
   50 FORMAT (10X,18HNON RECURRING COST,/)
   60 FORMAT (10X,42HED AND D                                  ,F8.3)
   70 FORMAT (10X,42HTOOLING                                   ,F8.3)
   80 FORMAT (10X,42HGROUND TEST HARDWARE                      ,F8.3)
   90 FORMAT (10X,42HFLIGHT TEST ARTICLES                      ,F8.3)
  100 FORMAT (10X,42HFLIGHT TEST S AND RP                      ,F8.3)
  110 FORMAT (52X,8H--------)
  120 FORMAT (10X,42HTOTAL NONRECURRING TPS COST               ,F8.3//)
  130 FORMAT (10X,28HRECURRING PRODUCTION COST   ,/)
  140 FORMAT (10X,51HSUSTAINING ENGINEERING          -     INCLUDED IN TFU
     1)
  150 FORMAT (10X,51HSUSTAINING TOOLING              -     INCLUDED IN TFU
```

Figure I-9. Source Listing — COSTOT

```
     1)
 160 FORMAT (10X,42HPRODUCTION ARTICLES (1)                      ,F8.3)
 170 FORMAT (10X,42HTEST ARTICLE CONVERSION                      ,F8.3)
 180 FORMAT (10X,42HTOTAL RECURRING PRODUCTION COST              ,F8.3//)
 190 FORMAT (10X,25HRECURRING OPERATIONS COST,/)
 200 FORMAT (10X,42HREPLENISHMENT S AND RP                       ,F8.3)
 210 FORMAT (10X,42HTOTAL RECURRING OPERATIONS COST              ,F8.3///)
 220 FORMAT (10X,42HTOTAL THERMAL PROTECTION SYS PROGRAM COSTS,F8.3)
     RETURN
     END
```

Figure I-9. Source Listing — COSTOT

```
      FUNCTION CURVEF(F,FSTAR)
C                 THIS FUNCTION IS USED TO COMPUTE OBSPL
      ITER=0
      SUMDEL=0.
      IF (FSTAR.GT.F) GO TO 30
                  FUNDAMENTAL FREQUENCY IS LESS THAN F
      DELDBP=4.
      FU=F
   10 FL=.5*FU
      IF (FL.LE.FSTAR) GO TO 20
      SUMDEL=SUMDEL+DELDBP
      FU=FL
      ITER=ITER+1
      IF (ITER.GT.100) GO TO 70
      GO TO 10
   20 DELDB=(FSTAR-FL)/(FU-FL)*DELDBP+SUMDEL
      GO TO 60
C                 FUNDAMENTAL FREQUENCY IS GREATER THAN F
   30 DELDBP=3.5
      FL=F
   40 FU=2.*FL
      IF (FU.GE.FSTAR) GO TO 50
      SUMDEL=SUMDEL+DELDBP
      FL=FU
      ITER=ITER+1
      IF (ITER.GT.100) GO TO 70
      GO TO 40
   50 DELDB=(FSTAR-FL)/(FU-FL)*DELDBP+SUMDEL
   60 CURVEF=DELDB
      RETURN
   70 WRITE (6,80) F,FSTAR
   80 FORMAT (30H0ERROR IN OBSPL COMPUTATION F=E12.4,3X,6HFSTAR=E12.4)
      CURVEF = -1.
      RETURN
      END
```

Figure I-10. Source Listing — CURVEF

```
      SUBROUTINE DRVTPS(T1,T2,T3,TS,TC)
      COMMON/WTA/
     1A          ,B          ,CHORD      ,E1RIB      ,E2RIB      ,E3RIB      ,
     2HBEAMA     ,HFNG1      ,HFNG2      ,HRIB       ,HRING      ,IDFNG1     ,
     3IDFNG2     ,KINDP      ,KINDS      ,LENGTH     ,DLPANL     ,LTUBE      ,
     4NRIBS      ,ODPOSR     ,ODPOST     ,ODRING     ,RADIUS     ,TBMLA      ,
     5TBMLC      ,TBMSA      ,TBMSC      ,TCORE      ,TCORN      ,TDOUBC     ,
     6TDOUBP     ,TEDGE      ,TFNG1      ,TINS1      ,TINS2      ,TINS3      ,
     7TPLATE     ,TPOST      ,T1RIB      ,T2RIB      ,TWRIB      ,TRIBL      ,
     8TRIBS      ,TRING1     ,TRING2     ,TSEAL      ,TSKIN1     ,TSKIN2     ,
     9TTUBE      ,WIDTH      ,WBEAMA     ,WBMLC      ,WBMSC      ,DWPANL     ,
     $WPOST      ,WRIBL      ,WRIBS      ,PBM        ,PCORE      ,PEDGE      ,
     $PINS1      ,PINS2      ,PINS3      ,PPOST      ,PRIB       ,PSEAL      ,
     $PSKIN1     ,PSKIN2     ,PTUBE      ,GBOLT      ,GCLAMP     ,GINSRT     ,
     $GINSUL     ,GNUTPL     ,GWASH
      COMMON/WTCOST/
     1KLIC       ,N          ,ACWT       ,KT         ,ITL ,LEN, WID, LTUBER
     2,MAWT,KK,AOP(7,7),KMUV(100,3),KSETUP(100,21),KRUN(100,21)
     3,KCC(5,21),TIME(7),TMAT(3),DIAMA(6),WTNUT(6),TBTABL(6)
     4,KCOSWT(100,3)
      COMMON/ZERO/
     1 TOPWT,TACWT,TMAWT,TTSHR,TTLBHR,TTLACO,TTVCOS,TTFCOS,TTMCOS,
     2TASYCO,LABHR,       LACOST,VCOST,TSTDHR,TLACOS,TVCOST,TFCOST
      COMMON/COMTOT/ CF,K1,STPS,AT,K2,BT,TDH,C,EGTH,NFTA,EFTS,NPA,ETA,
     1EFA,NFLTS,TUNWT
      COMMON/ALPHAN/
     1ANAM1(22) ,ANAM2(22),ANAM3(22)
      DIMENSION IA(75),IB(17)
      EQUIVALENCE (IA,A)
      EQUIVALENCE (IB,TOPWT)
      REAL IDFNG1, IDFNG2, K1, K2, LENGTH, LTUBE
C
C ***  INITIALIZE INPUT VARIABLES
C
      DO 10 I=1,75
      IA(I)=0
   10 CONTINUE
      DO 20 I=1,17
      IB(I)=0
   20 CONTINUE
      CF=3.3
      K1=.00171
      STPS=22000.
      AT=.667
      K2=6.58
      BT=.187
      TDH=14.13
      C=-.14
      EGTH=2.45
      NFTA=2
      EFTS=.67
      NPA=1
      ETA=0.3
      EFA=0.003
      NFLTS=444
      TINS1=T1*12.0
      TINS2=T2*12.0
      TINS3=T3*12.0
      TSKIN1=TS
      TSKIN2=TC
```

Figure I-11. Source Listing — DRVTPS

```
      WRITE (6,130)
C
C *** READ WEIGHT-COST INPUT
C
      READ (5,140) KINDP,KINDS,LENGTH,WIDTH,DLPANL,DWPANL,A,B
      READ (5,150) PINS1,PINS2,PINS3
      WRITE (6,160) KINDP,LENGTH,WIDTH,DLPANL,DWPANL,A,B,KINDS,TINS1,TIN
     1S2,TINS3,PINS1,PINS2,PINS3
      IF (KINDP.GT.0.AND.KINDP.LT.4) GO TO 30
      WRITE (6,170)
      STOP
   30 GO TO (40,50,60), KINDP
C
C *** KINDP = 1
C
   40 READ (5,180) NRIBS,CHORD,RADIUS,PSKIN1,PSKIN2
      WRITE (6,190) NRIBS,CHORD,RADIUS,TSKIN1,TSKIN2,PSKIN1,PSKIN2
      GO TO 70
C
C *** KINDP = 2
C
   50 READ (5,150) GINSRT,TCORE,TEDGE,PCORE,PEDGE,PSKIN1,PSKIN2
      WRITE (6,200) GINSRT,TCORE,TEDGE,TSKIN1,TSKIN2,PCORE,PEDGE,PSKIN1,
     1PSKIN2
      GO TO 70
C
C *** KINDP = 3
C
   60 READ (5,180) NRIBS,HRIB,TEDGE,PRIB,PEDGE,PSKIN1
      READ (5,150) E1RIB,E2RIB,E3RIB,T1RIB,T2RIB,TWRIB
      WRITE (6,210) NRIBS,HRIB,TEDGE,TSKIN1,PRIB,PEDGE,PSKIN1,E1RIB,E2RI
     1B,E3RIB,T1RIB,T2RIB,TWRIB
   70 IF (KINDS.GT.0.AND.KINDS.LT.4) GO TO 80
      WRITE (6,220)
      STOP
   80 GO TO (90,100,110), KINDS
C
C *** KINDS = 1
C
   90 READ (5,150) GBOLT,GNUTPL,GWASH,TCORN,TPOST,PPOST,ODPOST,TPLATE
      READ (5,150) TFNG1,TTUBE,PTUBE,LTUBE,TSEAL,PSEAL,TDOUBC,TDOUBP
      READ (5,150) TBMLA,TBMSA,HBEAMA,WBEAMA,PBM
      WRITE (6,230) GBOLT,GNUTPL,GWASH,TCORN,TPOST,PPOST,ODPOST,TPLATE,T
     1FNG1,TTUBE,PTUBE,LTUBE,TSEAL,PSEAL,TDOUBC,TDOUBP,TBMLA,TBMSA,HBEAM
     2A,WBEAMA,PBM
      GO TO 120
C
C *** KINDS = 2
C
  100 READ (5,150) GBOLT,GNUTPL,GWASH,GINSUL,TPOST,PPOST,WPOST
      WRITE (6,240) GBOLT,GNUTPL,GWASH,GINSUL,TPOST,PPOST,WPOST
      GO TO 120
C
C *** KINDS = 3
C
  110 READ (5,150) GBOLT,GNUTPL,GWASH,GCLAMP,TPOST,PPOST,ODPOST,ODPOSR,O
     1DRING,HRING,TFNG1,TTUBE,PTUBE,IDFNG1,IDFNG2,HFNG1,HFNG2,TRING1,TRI
     2NG2
      READ (5,150) TBMLC,TBMSC,WBMLC,WBMSC,PBM,TRIBL,TRIBS,WRIBL,WRIBS
      WRITE (6,250) GBOLT,GNUTPL,GWASH,GCLAMP,TPOST,PPOST,ODPOST,ODRING,
```

Figure I-11. Source Listing — DRVTPS, Contd

```
     1HRING,TRING1,TRING2,HFNG1,HFNG2,ODPOST,TFNG1,TTUBE,PTUBE,IDFNG1,ID
     2FNG2,TRIBL,TRIBS,TBMLC,TBMSC,WBMLC,WBMSC,PBM,WRIBL,WRIBS
  120 WRITE (6,260)
      CALL WTTPS
      CALL COSTOT
      RETURN
C
  130 FORMAT (1H1)
  140 FORMAT (2I4,6E8.0)
  150 FORMAT (10E8.0)
  160 FORMAT (46H1***** W E I G H T - C O S T   I N P U T *****//10X,5HK
     1INDP,9X,6HLENGTH,10X,5HWIDTH,9X,6HDLPANL,9X,6HDWPANL,14X,1HA,14X,1
     2HB/I15,6F15.3//10X,5HKINDS,10X,5HTINS1,10X,5HTINS2,10X,5HTINS3,10X
     3,5HPINS1,10X,5HPINS2,10X,5HPINS3/I15,6F15.3)
  170 FORMAT (65H0***** KIND OF PANEL FLAG, KINDP, WAS NOT PROPERLY ENTE
     1RED. *****)
  180 FORMAT (I8,9E8.0)
  190 FORMAT (//10X,5HNRIBS,10X,5HCHORD,9X,6HRADIUS,9X,6HTSKIN1,9X,6HTSK
     1IN2,9X,6HPSKIN1,9X,6HPSKIN2/I15,6F15.3)
  200 FORMAT (//9X,6HGINSRT,10X,5HTCORE,10X,5HTEDGE,9X,6HTSKIN1,9X,6HTSK
     1IN2,10X,5HPCORE,10X,5HPEDGE,9X,6HPSKIN1,9X,6HPSKIN2/9F15.3)
  210 FORMAT (//10X,5HNRIBS,11X,4HHRIB,10X,5HTEDGE,9X,6HTSKIN1,11X,4HPRI
     1B,10X,5HPEDGE,9X,6HPSKIN1/I15,6E15.3//10X,5HE1RIB,10X,5HE2RIB,10X,
     25HE3RIB,10X,5HT1RIB,10X,5HT2RIB,10X,5HTWRIB/6F15.3)
  220 FORMAT (69H0***** KIND OF STRUCTURE FLAG, KINDS, WAS NOT PROPERLY
     1ENTERED. *****)
  230 FORMAT (//10X,5HGBOLT,9X,6HGNUTPL,10X,5HGWASH,10X,5HTCORN,10X,5HTP
     1OST,10X,5HPPOST,9X,6HODPOST/7F15.3//9X,6HTPLATE,10X,5HTFNG1,10X,5H
     2TTUBE,10X,5HPTUBE,10X,5HLTUBE,10X,5HTSEAL,10X,5HPSEAL/7F15.3//9X,6
     3HTDOUBC,9X,6HTDOUBP,10X,5HTBMLA,10X,5HTBMSA,9X,6HHBEAMA,9X,6HWBEAM
     4A,12X,3HPBM/7F15.3)
  240 FORMAT (//10X,5HGBOLT,9X,6HGNUTPL,10X,5HGWASH,9X,6HGINSUL,10X,5HTP
     1OST,10X,5HPPOST,10X,5HWPOST/7F15.3)
  250 FORMAT (//10X,5HGBOLT,9X,6HGNUTPL,10X,5HGWASH,9X,6HGCLAMP,10X,5HTP
     1OST,10X,5HPPOST,9X,6HODPOST/7F15.3//9X,6HODRING,10X,5HHRING,9X,6HT
     2RING1,9X,6HTRING2,10X,5HHFNG1,10X,5HHFNG2,9X,6HODPOSR/7F15.3//10X,
     35HTFNG1,10X,5HTTUBE,10X,5HPTUBE,9X,6HIDFNG1,9X,6HIDFNG2,10X,5HTRIB
     4L,10X,5HTRIBS/7F15.3//10X,5HTBMLC,10X,5HTBMSC,10X,5HWBMLC,10X,5HWB
     5MSC,12X,3HPBM,10X,5HWRIBL,10X,5HWRIBS/7F15.3)
  260 FORMAT (36H0***** E N D   O F   I N P U T *****)
      END
```

Figure I-11. Source Listing — DRVTPS, Contd

```
      SUBROUTINE FATIG(NSECT,TC,TS)
C
C         A C O U S T I C   F A T I G U E   A N A L Y S I S
C
C
C        DESCRIPTION OF INPUT PARAMETERS
C
C                    AE       NOZZLE EXIT AREA
C                    AI       MOMENT OF INERTIA
C                    AW       PANEL LENGTH
C                    AMACH    LOCAL MACH NUMBER
C                    BW       PANEL WIDTH
C                    C        COEFFICIENTS OF A LEAST SQUARES, 3RD ORDER
C                             CURVE FIT OF ALLOWABLE S-N DATA
C                    D        NOZZLE DIAMETER
C                    DT       DURATION OF NOISE IN SECONDS
C                    DVEH     VEHICLE DIAMETER
C                    EP       PANELS YOUNGS MODULUS
C                    HPAN     THICKNESS
C                    HC       THICKNESS IN HONEYCOMB PANEL (MIDDLE)
C                    HF       THICKNESS IN HONEYCOMB PANEL (OUTSIDE)
C                    IPAD=0      VEHICLE IS IN FLIGHT
C                    IPAD=1      VEHICLE IS IN THE PAD
C                    KFLEX=0     RIGID AND SYMMETRICAL SUPPORTING STRUCTURE
C                    KFLEX=1     FLEXIBLE AND/OR UNSYMMETRICAL SUPPORTING
C                                STRUCTURE
C                    NENG     NUMBER OF ENGINES
C                    NPAN  =1    RECTANGULAR ISOTROPIC PLATE
C                    NPAN  =2    RECTANGULAR HONEYCOMB SANDWICH PANEL
C                    NPAN  =3    INTEGRALLY STIFFENED PANEL
C                    QL       LOCAL DYNAMIC PRESSURE
C                    REY      REYNOLDS NUMBER
C                    RHO      MATERIAL DENSITY
C                    TJ       JET THRUST
C                    TT       TOTAL THRUST IN LB
C                    VJ       JET VELOCITY
C                    VS       LOCAL SPEED OF SOUND
C                    VU       LOCAL VELOCITY
C                    VV       VEHICLE VELOCITY
C                    WEJ      WEIGHT FLOW OF JET ENGINE
C                    WER      WEIGHT FLOW OF ROCKET ENGINE
C                    VU       LOCAL VELOCITY
C                    XI       DISTANCE BETWEEN BOOSTER ENGINE AND POINT OF
C                             INTEREST
C                    XJ       DISTANCE TO EXIT PLANE OF JET ENGINE
C                    XL       BOUNDARY LAYER LENGTH
C                    YP       Y DISTANCE IN A NEAR FIELD LESS THAN 200 FT.
      COMMON /BLOCKT/
     1    TBBA(6),   TBK1(6),   TBK2(6)
      COMMON/SONIC1/  AE      ,AI      ,AW      ,AMACH   ,BW      ,C(4)    ,
     1D       ,DT(4)   ,DVEH    ,EP      ,HPAN    ,HC      ,HF      ,IPAD    ,
     2KFLEX   ,NENG    ,NPAN    ,QL      ,REY     ,RHOP    ,TJ      ,TT      ,
     3VJ      ,VS      ,VU      ,VV      ,WEJ     ,WER     ,IPF(4)  ,XI      ,
     4XJ      ,XL      ,YP      ,IPFI    ,AIY     ,DREF    ,YCL
      COMMON/APP1/NOAPP
      DIMENSION ANL(4),ANRMS(4),ANML(4),SCR(4),PF(4),CY(4),SLD(4),
     1ANCR(4)
C
      DATA AMU/.3/
      DATA CCC/.02/
```

Figure I-12. Source Listing — FATIG

```
      DATA CG/32.174/
      DATA NDIM/6/
      DATA PI/3.14159/
      DATA TBBA  /
     1   1.,     1.5,    2.0,    2.5,    3.0  1.E30/
      DATA TBK1  /
     1    27.89, 20.63, 18.45, 17.61, 17.08, 16.12/
      DATA TBK2  /
     1    19.74, 14.26, 12.34, 11.45, 10.97,  9.87/
C
C
   10 WRITE (6,350)
C
C                COMPUTE FUNDAMENTAL FREQUENCIES
      IF (NSECT.EQ.1.OR.NSECT.EQ.2.OR.NSECT.EQ.3.OR.NSECT.EQ.4) NPAN=3
      IF (NSECT.EQ.5.OR.NSECT.EQ.6) NPAN=4
      HPAN=TS
      IF (TS.EQ.0.) HPAN=TC
      HPAN2=HPAN*HPAN
      HPAN3=HPAN2*HPAN
      IF (AW.LE.BW) GO TO 20
      TEM1=AW
      AW=BW
      BW=TEM1
   20 AL2=AW*AW
      AL4=AL2*AL2
      AMASS=RHOP*HPAN/CG
      BA=BW/AW
C
      FSTAR=1.
      IF (KFLEX.NE.0) FSTAR=.25
      GO TO (30,40,60,70), NPAN
C                RECTANGULAR ISOTROPIC PLATE
   30 DR=EP*HPAN**3/(12.*(1.-AMU**2))
      AK=TABLE(BA,TBBA,TBK1,NDIM)
      IF (AK.EQ.0) GO TO 340
      GO TO 50
C                RECTANGULAR HONEYCOMB SANDWICH PANEL
   40 HF=.5*(HPAN-HC)
      DR=EP*HPAN*HF*HC/1.82
      AK=TABLE(BA,TBBA,TBK2,NDIM)
      IF (AK.EQ.0) GO TO 340
   50 FREQ=AK/(2.*PI*AL2*SQRT(AMASS/DR))*FSTAR
      GO TO 80
C                INTEGRALLY STIFFENED PANEL
   60 DR=EP*HPAN3/(12.*(1.-AMU**2))
      DX=DR+EP*AI/(BW*12.)
      DY=DR
      AKM=PI/AW
      AKN=PI/BW
      AKM2=AKM*AKM
      AKN2=AKN*AKN
      AKTAU=(SQRT(DX/12.)*AKM2+SQRT(DY/12.)*AKN2)**2
      AKI=(DX/12.)*(AKM2+AKN2)**2
      SRT=AKTAU/AKI
      HEQ=HPAN*SRT**(1./3.)
      OMEGA=SQRT(AKTAU*12./AMASS)
      FREQ=OMEGA/(2.*PI)*FSTAR
      GO TO 80
C                CORRUGATED PANEL
```

Figure I-12. Source Listing — FATIG, Contd

```
 70 AIX=AI
    DY=EP*AIX/(AW*12.)
    DX=EP*AIY/(BW*12.)
    AKM=PI/AW
    AKN=PI/BW
    AKM2=AKM*AKM
    AKN2=AKN*AKN
    AKTAU=(SQRT(DX)*AKM2+SQRT(DY)*AKN2)**2
    OMEGA=SQRT(AKTAU/AMASS)
    FREQ=OMEGA/(2.*PI)*FSTAR
 80 CONTINUE
    WRITE (6,400) FREQ
C
C                NOISE COMPUTATIONS
C
C
    DO 200 I=1,IPFI
    IPFF=IPF(I)
    GO TO (90,100,140,190), IPFF
C               1.  BOUNDARY LAYER
 90 SIGMAX=.37*REY**(-.2)*(1.+(REY/2.9E7)**2)**.1
    FZERO=8.*VU/SIGMAX/XL
C               PF IS SPECTRUM PRESSURE
    PF(1)=QL*SQRT(.012/((1.+.14*AMACH**2)*FZERO*(1.+(FREQ/FZERO)**2)**
   11.5))
    FPLF=20.*ALOG10(PF/41.8E-8)
    WRITE (6,410) FPLF,REY,AMACH,QL,VU
    GO TO 200
C
C               2.  ROCKET ENGINE NOISE    (BOOSTE AND ORBITER)
100 VEXH=TT*CG/WER
    FDV=FREQ*D/VEXH
    IF (FDV.LE..175) GO TO 110
    RTERM=-.222-1.315*ALOG10(FDV)
    GO TO 120
110 RTERM=.625-.202*ALOG10(FDV)
120 XZERO=D*10.**RTERM
    R=XI+XZERO
    IF (IPAD.EQ.0) GO TO 130
    IF (XZERO.GT.(DREF+YCL)) R=SQRT((XI+DREF)**2+(XZERO-DREF-YCL)**2)
    IF (XZERO.GT.DREF.AND.XZERO.LE.(DREF+YCL)) R=SQRT((XI+DREF)**2+(YC
   1L-XZERO+DREF)**2)
    IF (XZERO.LE.DREF) R=SQRT((XI+XZERO)**2+YCL**2)
C               COMPUTE SPL SOUND PRESSURE LEVEL
130 IF (FDV.LE..016) SPL=70.+16.6*ALOG10(FDV/.003)
    IF (FDV.LT..152.AND.FDV.GT..016) SPL=82.
    IF (FDV.GE..152) SPL=70.-16.6*ALOG10(FDV/.8)
    CAPID=VS/(PI*DVEH)
    DELBP=0.
    IF (FREQ.GE.CAPID) DELBP=6.0
C               OBSPL IS OCTAVE BAND SOUND PRESSURE LEVEL
    OBSPL=10.*ALOG10(.676*TT**2*CG/WER)+SPL-20.*ALOG10(R)+DELBP
    BWD1=BANDW(FREQ)
    SPLF=OBSPL-10.*ALOG10(BWD1)
    WRITE (6,420) SPLF,XZERO
    PF(I)=41.8E-8*10.**(SPLF/20.)
    GO TO 200
C
C               3.  JET FLYBACK ENGINE NOISE ON VEHICLE
140 VR=ABS(VV-VJ)
```

Figure I-12. Source Listing — FATIG, Contd

```
      DJ=SQRT(4.*AE/PI)
      RHOF=WEJ/(AE*VJ)
      FVRLG=145.+100.*ALOG10(VR/1600.)
C                SPL200 IS OVERALL SOUND PRESSURE LEVEL FOR Y=200FT.
      SPL200=FVRLG+10.*ALOG10(RHOF**2*AE)
C                SPLNF IS SOUND PRESSURE LEVEL AT YP DISTANCE
C                NONDIMESIONALIZE DISTANCES
      Y200DJ=200./DJ
      Y30DJ=30./DJ
      Y25DJ=2.5/DJ
      YPDJ=YP/DJ
      TERM1=20.*ALOG10(Y200DJ/Y30DJ)
      TERM2=16.*ALOG10(Y30DJ/Y25DJ)
      IF (YPDJ.GT.200.) GO TO 170
      IF (YPDJ.LT.30.) GO TO 150
      DELDB=20.*ALOG10(Y200DJ/YPDJ)
      GO TO 180
  150 IF (YPDJ.LT.2.5) GO TO 160
      DELDB=TERM1+16.*ALOG10(Y30DJ/YPDJ)
      GO TO 180
  160 IF (YPDJ.LT.1.) GO TO 170
      DELDB=TERM1+TERM2+14.*ALOG10(Y25DJ/YPDJ)
      GO TO 180
  170 WRITE (6,360) YP
      GO TO 340
  180 SPLNF=SPL200+DELDB+6.
      FREQP=.8*VJ/DJ
      BWD=BANDW(FREQ)
      OBMAX=SPLNF-5.
      CVF=CURVEF(FREQP,FREQ)
      IF (CVF.EQ.-1) GO TO 340
      OBSPL=OBMAX-CVF
      SPLF=OBSPL-10.*ALOG10(BWD)
      WRITE (6,370) SPLF
      PF(I)=41.8E-8*10.**(SPLF/20.)
      GO TO 200
C
C                4.  JET SCRUBBING ON BODY
C                PE IS PRESSURE AT NOZZLE EXIT
  190 PE=TJ*1.275/DJ**2
C                DX IS JET DIAMETER AT X FEET
      DX=DJ*(1.+.244*XJ/DJ)
C                PX IS SCRUBBING PRESSURE
      PX=.155*TJ/DX**2
      SPLX=20.*ALOG10(PX/41.8E-8)
      FREQP=.4*VJ/DJ
      BWD=BANDW(FREQ)
      OBMAX=SPLX-5.
      CVF=CURVEF(FREQP,FREQ)
      IF (CVF.EQ.-1) GO TO 340
      OBSPL=OBMAX-CVF
      SPLF=OBSPL-10.*ALOG10(BWD)
      WRITE (6,430) SPLF
      PF(I)=41.8E-8*10.**(SPLF/20.)
  200 CONTINUE
C
C
C                DYNAMIC STRESSES
C
      BWD=.04*FREQ
```

Figure I-12. Source Listing – FATIG, Contd

```
      SUM1=0.
      SUM2=0.
      SBWD=SQRT(BWD)
      DO 320 I=1,IPFI
      PBAR=PF(I)*SBWD
      CY(I)=0.
      SCR(I)=0.
      SCON=.5
      IF (KFLEX.NE.0.) SCON=.75
      DCON=4.089
      IF (KFLEX.NE.0.) DCON=20.445
      GO TO (210,220,230,240), NPAN
C                   SMAX IS MAXIMUM BENDING STRESS
C                   YMAX IS MAXIMUM DEFLECTION
  210 SMAX=SCON*AL2*PBAR/HPAN2
      YMAX=DCON*PBAR*AL4/(EP*HPAN**3)
      SLD(I)=100.*SMAX
      GO TO 250
  220 HEFF=1.817*(HC*HF*HPAN)**(1./3.)
      SMAX=SCON*PBAR/HEFF**2*AL2
      YMAX=DCON*PBAR*AL4/(EP*HEFF**3)
      SLD(I)=100.*SMAX
      GO TO 250
  230 SMAX=SCON*PBAR*AL2/HEQ**2
      YMAX=DCON*PBAR*AL4/(EP*HEQ**3)
      SD=25.*SMAX
      SLD(I)=4.*SD
      GO TO 250
  240 HEFF=(10.9*((SQRT(AIY/BW)/AW**2+SQRT(AIX/AW)/BW**2)/(1./AW**2+1./B
     1W**2))**2)**0.3333
      SMAX=SCON*PBAR*AL2/HEFF**2
      YMAX=DCON*PBAR*AL4/(EP*HEFF**3)
      SLD(I)=100.*SMAX
  250 WRITE (6,440) SLD(I),YMAX
C                   STRESS REVERSALS PER MISSION OR FOR VEHICLE LIFETIME
      IPFF=IPF(I)
      ANL(I)=FREQ*DT(IPFF)
      ANRMS(I)=.61*ANL(I)
      CALL MININO(C,SLD(I),ANRMS(I),CY(I),SCR(I))
      IF (NOAPP.EQ.2) GO TO 340
      GO TO (260,270,280,290), IPFF
  260 WRITE (6,450) SCR(I)
      GO TO 300
  270 WRITE (6,380) SCR(I)
      GO TO 300
  280 WRITE (6,460) SCR(I)
      GO TO 300
  290 WRITE (6,390) SCR(I)
  300 IF (SCR(I).EQ.0.) GO TO 320
      ANCR(I)=1.261*ANRMS(I)*SLD(I)/SCR(I)
      WRITE (6,470) ANCR(I)
      SUM1=SCR(I)**2+SUM1
      SUM2=ANRMS(I)*SLD(I)+SUM2
      X=ALOG10(ANCR(I))
      ALLST=(C(1)+C(2)*X+C(3)*X**2+C(4)*X**3)*1000.
      IF (ALLST.GE.SCR(I)) GO TO 310
      WRITE (6,480) ALLST
      GO TO 320
  310 WRITE (6,490) ALLST
  320 CONTINUE
```

Figure I-12. Source Listing — FATIG, Contd

```
      IF (SUM1.EQ.0.) GO TO 340
      SBAR=SQRT(SUM1)
      ANBAR=1.261*SUM2/SBAR
      WRITE (6,500) SBAR,ANBAR
      X=ALOG10(ANBAR)
      ALLST=(C(1)+C(2)*X+C(3)*X**2+C(4)*X**3)*1000.
      IF (ALLST.GE.SBAR) GO TO 330
      WRITE (6,480) ALLST
      GO TO 340
  330 WRITE (6,490) ALLST
  340 RETURN
C
  350 FORMAT (1H1)
  360 FORMAT (18H0Y-DISTANCE ERROR=E12.4)
  370 FORMAT (14H ABES NOISE = ,F6.1,3H DB)
  380 FORMAT (39H ROCKET ENGINE NOISE CRITICAL STRESS = ,E12.4,4H PSI)
  390 FORMAT (39H JET SCRUBBING NOISE CRITICAL STRESS = ,E12.4,4H PSI)
  400 FORMAT (13H FREQUENCY = ,F7.1,3H HZ/)
  410 FORMAT (24H BOUNDARY LAYER NOISE = ,F6.1,21H DB - REYNOLDS NO. = ,
     1E12.4,13H, MACH NO. = ,E12.4/20H DYNAMIC PRESSURE = ,E12.4,13H, VE
     2LOCITY = ,E12.4)
  420 FORMAT (23H ROCKET ENGINE NOISE = ,F6.1,31H DB - APPARENT NOISE SO
     1URCE AT ,F6.1,3H FT)
  430 FORMAT (23H JET SCRUBBING NOISE = ,F6.1,3H DB)
  440 FORMAT (26H0MAXIMUM BENDING STRESS = ,F10.0,4H PSI/26H MAXIMUM RMS
     1 DEFLECTION = ,F10.5,3H IN)
  450 FORMAT (40H BOUNDARY LAYER NOISE CRITICAL STRESS = ,E12.4,4H PSI)
  460 FORMAT (44H JET FLYBACK ENGINE NOISE CRITICAL STRESS = ,E12.4,4H P
     1SI)
  470 FORMAT (27H NO. OF STRESS REVERSALS = ,E12.4)
  480 FORMAT (35H ***PANEL IS SUSCEPTIBLE TO FAILURE/39H    CRITICAL STR
     1ESS MUST BE REDUCED TO ,E12.4,21H PSI TO AVOID FAILURE)
  490 FORMAT (36H ***PANEL IS GOOD FOR THIS CONDITION/40H    CRITICAL ST
     1RESS MAY BE INCREASED TO ,E12.4,4H PSI)
  500 FORMAT (29H0COMPOSITE CRITICAL STRESS = ,E12.4,4H PSI/27H NO. OF S
     1TRESS REVERSALS = ,E12.4)
      END
```

Figure I-12. Source Listing — FATIG, Contd

```
      SUBROUTINE INPUT1
C
      DIMENSION CONF(3),TURB(4),WALT(4),ANGL(4),QLOC(6),ID(9,9)
      DIMENSION A(20),ALPHA(99),ALT(99),AX(9,9,9),AY(9,9,9),BETA(99),
     1DIST(9),E(20,99),EAT(20,99),EDOT(20,99),EMIS(9),FCY(20,99),
     2FNET(20),FT(20),FTU(20,99),HINSD(99),MAT(9,9),MPT(9,9),MR(9,18),
     3NI(18),NR(18),PINP(99),Q(9),QCONL(9),QCONT(9),QINP(99),QNET(9),
     4RHO(9),T(20,99),TAMP(9,9),TEMP(9,9),TIME(99),TINSD(99),VFACT(9,18)
     5,VINF(99),X(9),XX(20),Y(9),ZZ(20),TALLW(9)
      COMMON  A        ,AL       ,ALPHA    ,ALT      ,AME      ,AMI      ,AOFA     ,
     1AROD    ,AS      ,AX       ,AY       ,BATA     ,BE       ,BETA     ,BF       ,
     2BFL     ,BL      ,DELTA    ,DIAM     ,DIST     ,DNX      ,DNY      ,DNZ      ,
     3DST     ,E       ,EALL     ,EAT      ,EDOT     ,EMIS     ,FCY      ,FNET     ,
     4FT      ,FTU     ,F07      ,HH       ,HINS     ,HINSD    ,ICONF    ,IQINP    ,
     5ITURB   ,IWALT   ,MAT      ,MPT      ,MR       ,NCOLM    ,NCR      ,NF       ,
     6NI      ,NPSG    ,NR       ,NRSG     ,NSECT    ,NSEG     ,NTRAJ    ,PE       ,
     7PI      ,PINP    ,Q        ,QCONL    ,QCONT    ,QINP     ,QNET     ,R        ,
     8RHO     ,RHOI    ,RYE      ,RYI      ,SL       ,SLS      ,STAAT    ,STI      ,
     9STOOP   ,T       ,TAMP     ,TAU      ,TC       ,TC1      ,TEMP     ,TI       ,
     $TIME    ,TINS    ,TINSD    ,TS       ,UF       ,VFACT    ,VI       ,VINF     ,
     $WROTE   ,X       ,XEMIS    ,XX       ,Y        ,ZZ       ,NCRC     ,TALLW    ,
     $NINS    ,FACC    ,NPRT
      COMMON/SONIC1/  AE       ,AI       ,AW       ,AMACH    ,BW       ,C(4)     ,
     1D       ,DT(4)   ,DVEH     ,EP       ,HPAN     ,HC       ,HF       ,IPAD     ,
     2KFLEX   ,NENG    ,NPAN     ,QL       ,REY      ,RHOP     ,TJ       ,TT       ,
     3VJ      ,VS      ,VU       ,VV       ,WEJ      ,WER      ,IPF(4)   ,XI       ,
     4XJ      ,XL      ,YP       ,IPFI     ,AIY      ,DREF     ,YCL
      DIMENSION ANL(4),ANRMS(4),ANML(4),SCR(4),PF(4),CY(4),SLD(4),
     1SPMAX(4),TITLE(13)
      NAMELIST/DATANU/ICONF,IQCON,IQINP,ITURB,IWALT,NANG,NCOLM,NSEG,
     1NMAT,NRSG,NPSG,NCR,NF,NSECT,DNX,DNY,DNZ,XDST,DIAM,AROD,XEMIS,STAAT
     2,DELTA,WROTE,STOOP,AS,R,HH,TS,TC,SL,SLS,BE,F07,UF,DST,EALL,BF,BFL,
     3BL,X,Y,QCONL,QCONT,NUTRAJ,NUDIM,NINS
      DATA CONF/ 6HPLATE , 6HCONE  , 6HSPHERE /
      DATA TURB/ 6HECKERT, 6HSPALDI, 6H      , 6HNG-CHI /
      DATA WALT/ 6HUNIFOR, 6HNONUNI, 6HM     , 6HFORM   /
      DATA ANGL/ 6HVARIED, 6HCONSTA, 6H      , 6HNT     /
      DATA QLOC/ 6HCALCUL, 6HINPUT , 6HINPUT , 6HATED  , 6HQ     , 1HT /
C
      NUDIM=0
      NUTRAJ=0
      NTRAJ=0
      WRITE (6,410)
      DO 20 I=1,10
      READ (5,420) JI,TITLE
      IF (EOF,5) 30,10
   10 WRITE (6,430) TITLE
      IF (JI.GT.0) GO TO 40
   20 CONTINUE
      WRITE (6,440)
   30 STOP
   40 IF (JI.NE.2) GO TO 50
      READ (5,DATANU)
      IF (NUDIM.EQ.0.AND.NUTRAJ.EQ.0) GO TO 300
      IF (NUDIM) 250,250,100
   50 READ (5,450) ICONF,IQCON,IQINP,ITURB,IWALT,NANG,NCOLM,NSEG,NMAT,NR
     1SG,NCRC,NSECT,NINS,NF,NPRT
      NPSG=14
      IF (NSECT.EQ.4) NPSG=12
      IF (NSECT.EQ.3.OR.NSECT.EQ.6) NPSG=10
```

Figure I-13. Source Listing — INPUT1

```
      READ (5,460) DNX,DNY,DNZ,XDST,DIAM,AROD,XEMIS,FACC
      READ (5,460) STAAT,DELTA,WROTE,STOOP
      READ (5,460) AS,R,HH,TS,TC,SL,SLS,BE
      READ (5,460) F07,UF,DST,EALL,CRN,BF,BFL,BL
      NCR=IFIX(CRN)
      READ (5,460) (TALLW(I),I=1,9)
      READ (5,460) (EMIS(I),I=1,9)
      READ (5,460) (RHO(I),I=1,9)
      DO 90 I=1,NMAT
      READ (5,450) ((ID(I,J),MPT(I,J)),J=1,8)
      DO 90 J=1,8
      IF (ID(I,J).EQ.0.) GO TO 90
      KK=MPT(I,J)
      IF (J.EQ.1) GO TO 70
      IF (ID(I,J).EQ.2) GO TO 70
      DO 60 K=1,KK
   60 AX(I,J,K)=AX(I,J-1,K)
      GO TO 80
   70 READ (5,460) (AX(I,J,K),K=1,KK)
   80 READ (5,460) (AY(I,J,K),K=1,KK)
   90 CONTINUE
  100 IF (NCOLM.GT.1) GO TO 110
      X(1)=1.
      K=1
      QCONL(1)=1.0
      QCONT(1)=1.0
      GO TO 170
  110 READ (5,460) (X(I),I=1,9)
      K=9
      IF (IQCON-2) 120,140,160
  120 DO 130 I=1,9
      QCONL(I)=1.0
  130 QCONT(I)=1.0
      GO TO 170
  140 READ (5,460) (QCONL(I),I=1,9)
      DO 150 I=1,9
  150 QCONT(I)=QCONL(I)
      GO TO 170
  160 READ (5,460) (QCONL(I),I=1,9)
      READ (5,460) (QCONT(I),I=1,9)
  170 READ (5,460) (Y(I),I=1,9)
      DO 180 J=1,NSEG
  180 READ (5,470) (MAT(I,J),TAMP(I,J),I=1,K)
      IF (NCOLM.EQ.1.OR.NRSG.EQ.0) GO TO 250
      DO 190 J=1,NRSG
  190 READ (5,480) NR(J),NI(J),(MR(I,J),VFACT(I,J),I=1,9)
      READ (5,450) IPFI,(IPF(I),I=1,4),IPAD,KFLEX,NPAN
      DO 240 N1=1,IPFI
      N2=IPF(N1)
      GO TO (200,210,220,230), N2
  200 READ (5,460) DT(N2),XL,REY,VU,QL,AMACH
      GO TO 240
  210 READ (5,460) DT(N2),TT,WER,D,VS,XI,DVEH,YCL,DREF
      GO TO 240
  220 READ (5,460) DT(N2),AE,VJ,WEJ,VV,TJ,XJ,YP
      GO TO 240
  230 READ (5,460) DT(N2)
  240 CONTINUE
      READ (5,460) HPAN,HC,AI,AIY,AW,BW,EP
      READ (5,460) (C(I),I=1,4),RHOP
```

Figure I-13. Source Listing — INPUT1, Contd

```
250 IF (NUDIM.EQ.1.AND.NUTRAJ.EQ.0) GO TO 300
    IF (JI.EQ.3) GO TO 300
    NTRAJ1=NTRAJ
    DO 260 I=1,99
    READ (5,490) TIME(I),ALT(I),VINF(I),ALPHA(I),BETA(I),HINSD(I),TINS
   1D(I),NREADT
    NTRAJ=I
    IF (NREADT.GT.0) GO TO 270
260 CONTINUE
    WRITE (6,500)
    STOP
270 IF (NUTRAJ.EQ.1) NTRAJ=NTRAJ1
    IF (NANG.LT.2) GO TO 290
    DO 280 I=2,NTRAJ
    ALPHA(I)=ALPHA(1)
280 BETA(I)=BETA(1)
290 WRITE (6,510) ((I,TIME(I),ALT(I),VINF(I),ALPHA(I),BETA(I),HINSD(I)
   1,TINSD(I)),I=1,NTRAJ)
300 NUDIM=0
    NUTRAJ=0
    DIST(1)=XDST
    IF (IWALT.LT.2) GO TO 320
    DO 310 I=2,NCOLM
310 DIST(I)=DIST(I-1)+0.5*(X(I)+X(I-1))
320 WRITE (6,520) CONF(ICONF),TURB(ITURB),TURB(ITURB+2),WALT(IWALT),WA
   1LT(IWALT+2),ANGL(NANG),ANGL(NANG+2),QLOC(IQINP),QLOC(IQINP+3)
    WRITE (6,530) DNX,DNY,DNZ
    WRITE (6,540) XDST,DIAM,AROD,XEMIS,STAAT,STOOP,DELTA,WROTE
    WRITE (6,550) (I,I=1,9)
    WRITE (6,640) (TALLW(I),I=1,NMAT)
    WRITE (6,650) (EMIS(I),I=1,NMAT)
    WRITE (6,660) (RHO(I),I=1,NMAT)
    WRITE (6,670)
    DO 330 I=1,NMAT
    WRITE (6,690) I,(AX(I,J,1),AY(I,J,1),J=1,4)
    DO 330 K=2,9
330 WRITE (6,700) (AX(I,J,K),AY(I,J,K),J=1,4)
    WRITE (6,680)
    DO 340 I=1,NMAT
    WRITE (6,690) I,(AX(I,J,1),AY(I,J,1),J=5,8)
    DO 340 K=2,9
340 WRITE (6,700) (AX(I,J,K),AY(I,J,K),J=5,8)
    WRITE (6,560)
    IF (NCOLM.GT.1) GO TO 350
    WRITE (6,570) Y,(MAT(1,I),I=1,9),(TAMP(1,I),I=1,9)
    GO TO 380
350 WRITE (6,580) X,QCONL,QCONT,(MAT(I,1),I=1,9),Y(1),(TAMP(I,1),I=1,9
   1)
    DO 360 J=2,NSEG
360 WRITE (6,590) J,(MAT(I,J),I=1,9),Y(J),(TAMP(I,J),I=1,9)
    WRITE (6,600)
    IF (NRSG.EQ.0) GO TO 380
    WRITE (6,610)
    DO 370 J=1,NRSG
370 WRITE (6,620) NR(J),NI(J),(MR(I,J),VFACT(I,J),I=1,9)
380 WRITE (6,710) AS,R,HH,TS,TC,SL,SLS,BE,F07,UF,DST,EALL,CRN,BF,BFL,B
   1L
    WRITE (6,720)IPAD,KFLEX,NPAN,DT,XL,REY,VU,QL,AMACH,TT,WER,D,VS,XI,
   1DVEH,YCL,DREF,AE,VJ,WEJ,VV,TJ,XJ,YP,HPAN,HC,AI,AIY,AW,BW,EP,C,RHOP
    WRITE (6,630)
```

Figure I-13. Source Listing — INPUT1, Contd

```
      IF (NCRC.LT.2) GO TO 400
      XX(1)=X(1)
      DO 390 I=2,NCOLM
  390 XX(I)=XX(I-1)+X(I)
  400 WRITE (6,410)
      RETURN
C
  410 FORMAT (1H1)
  420 FORMAT (I1,13A6)
  430 FORMAT (1X13A6)
  440 FORMAT (////94H0***** NUMBER OF TITLE CARDS IS GREATER THAN 10 OR
     1JI WAS NOT ENTERED ON LAST TITLE CARD *****)
  450 FORMAT (20I4)
  460 FORMAT (10F8.0)
  470 FORMAT (9(I2,F6.0))
  480 FORMAT (I2,I6,9(I2,F6.0))
  490 FORMAT (7F8.0,I24)
  500 FORMAT (////87H0***** NUMBER OR TRAJECTORY CARDS IS GREATER THAN 9
     10 OR LAST CARD WAS NOT FLAGGED *****)
  510 FORMAT (///44H0***** T R A J E C T O R Y   I N P U T *****//4X1HI8
     1X7HTIME(I)9X6HALT(I)8X7HVINF(I)7X8HALPHA(I)8X7HBETA(I)7X8HHINSD(I)
     27X8HTINSD(I)//(I5,3F15.0,2F15.4,E15.4,F15.4))
  520 FORMAT (/////25H     PROGRAM OPTIONS USED/27H         CONFIGURATION
     1-      ,A6/27H          TURBULENT HEATING- ,2A6/27H        WALL TEMPE
     2RATURE-   ,2A6/27H          ANGLE OF ATTACK-   ,2A6/27H         LOCAL
     3HEAT FLUX-    ,2A6/)
  530 FORMAT (/5X,46HDIRECTION COSINES OF OUTER NORMAL FROM SURFACE/14H
     1         DNX = ,F7.4/14H          DNY = ,F7.4/14H          DNZ = ,F7.4/)
  540 FORMAT (/5X,30HDISTANCE FROM LEADING EDGE       ,F8.4,3H FT/35H      B
     1ODY DIAMETER                      ,F8.4,3H FT/35H     SHOULDER RADIUS/B
     2ODY DIAMETER ,F8.4/35H     EXTERNAL SURFACE EMISSIVITY    ,F6.2//35
     3H     INITIAL TIME                    ,F8.1,4H SEC/35H     END TIME
     4                          ,F8.1,4H SEC/35H     CALCULATION TIME INTERVA
     5L     ,F8.1,4H SEC/35H     PRINT OUT INTERVAL              ,F8.1,4H
     6SEC//)
  550 FORMAT (///50H0***** M A T E R I A L   P R O P E R T I E S *****//
     116H MATERIAL NUMBER,9(7X,1H-,I1,1H-))
  560 FORMAT (///45H0***** C O N D U C T I O N   I N P U T *****//)
  570 FORMAT (108H SEGMENT NUMBER                -1-        -2-        -3-
     1 -4-        -5-        -6-        -7-        -8-        -9-/18H THICKNE
     2SS FT     ,9F10.4/18H MATERIAL          ,9I10/18H INITIAL TEMP. R
     3,9F10.0//)
  580 FORMAT (111H COLUMN NUMBER, I              -1-        -2-        -3-
     1     -4-        -5-        -6-        -7-        -8-        -9-/21H WIDT
     2H, X(I) FT       ,9F10.4/16H HEATING FACTORS/21H    LAMINAR
     3   ,9F10.1/21H    TURBULENT          ,9F10.1//21H SEG.NO., J  =    -1
     4-,I10,1H*,I9,7I10/14H THICK.,Y(J) =,F7.4,F10.0,2H**,F8.0,7F10.0)
  590 FORMAT (/18X,1H-,I1,1H-,9I10/F21.4,9F10.0)
  600 FORMAT (1X,60(1H-)//5X,8H--NOTE--/27H            * = MATERIAL NUMBER/3
     17H         ** = INITIAL TEMPERATURE DEG R//)
  610 FORMAT (/55H0***** R A D I A T I O N   I N T E R C H A N G E ****
     1*//54H SEG NO.  NI    INTERCHANGE NEIGHBORS AND VIEW FACTORS/)
  620 FORMAT (1X,2H (,I2,1H),I5,2X,9(2H (,I2,1H),F6.3)))
  630 FORMAT (///36H0***** E N D   O F   I N P U T *****)
  640 FORMAT (18H0ALLOWABLE TEMP. R,9F10.3)
  650 FORMAT (11H0EMISSIVITY7X9F10.3)
  660 FORMAT (18H0MATERIAL DENSITY 9F10.3)
  670 FORMAT (///16H MATERIAL NUMBER,8X14HHEAT  CAPACITY,9X20HTHERMAL CO
     1NDUCTIVITY,9X14HYOUNGS MODULUS,8X22HTHERMAL EXPANSION COEF/12X4(12
     2X2HAX,10X2HAY))
```

Figure I-13. Source Listing — INPUT1, Contd

```
680 FORMAT (///16H MATERIAL NUMBER,8X14HYIELD STRENGTH,9X20HULT TENSILINP 241
   1E STRENGTH,5X22HLARSON-MILLER STRAIN 1,4X22HLARSON-MILLER STRAIN 2INP 242
   2/12X4(12X2HAX,10X2HAY))                                          INP 243
690 FORMAT (/I9,7X,4(2X2E12.3))                                      INP 244
700 FORMAT (16X,4(2X2E12.3))                                         INP 245
710 FORMAT (///36H0***** S T R E S S   I N P U T *****//13X2HAS,14X1HRINP 246
   1,13X2HHH,13X2HTS,13X2HTC,13X2HSL,12X3HSLS,13X2HBE/8E15.3//12X3HF07INP 247
   2,13X2HUF,12X3HDST,11X4HEALL,12X3HCRN,13X2HBF,12X3HBFL,13X2HBL/8E15INP 248
   3.3)                                                              INP 249
720 FORMAT (///38H0***** F A T I G U E   I N P U T *****//11X4HIPAD10XINP 250
   15HKFLEX,11X4HNPAN,10X5HDT(1),10X5HDT(2),10X5HDT(3),10X5HDT(4),13X2INP 251
   2HXL/3I15,5E15.3//12X3HREY,13X2HVU,13X2HQL,10X5HAMACH,13X2HTT,12X3HINP 252
   3WER,14X1HD,13X2HVS/8E15.3//13X2HXI,11X4HDVEH,12X3HYCL,11X4HDREF,13INP 253
   4X2HAE,13X2HVJ,12X3HWEJ,13X2HVV/8E15.3//13X2HTJ,13X2HXJ,13X2HYP,11XINP 254
   54HHPAN,13X2HHC,13X2HAI,12X3HAIY,13X2HAW/8E15.3//21X2HBW,13X2HEP,11INP 255
   6X4HC(1),11X4HC(2),11X4HC(3),11X4HC(4),11X4HRHOP/8X7E15.3)        INP 256
    END                                                              INP 257-
```

Figure I-13. Source Listing — INPUT1, Contd

```
      SUBROUTINE MININO(DI,SLD,CYL,CY,SCR)
      DIMENSION  DI(4)
      COMMON/APP1/NOAPP
      DIMENSION C(3)
      DATA C / 2.631102E-02, -2.635E-02, -4.939331E-01 /, PI / 3.14159 /
      NOAPP=0
      CYMAX=CYL
      XIU=1.E30
      ETAU=1.0
      XIL=0.0
      ETAL=0.0
      L=0
      DO 10 I=L,10
      ETA=0.999/10.**I
      CY=ETA*CYL
      C1=APP(SLD,CY,CYL,DI)
      IF (NOAPP.NE.0) GO TO 100
      C2=ALL(DI,CY)
      XI=C2-C1
      IF (XI.GE.XIU) GO TO 90
      IF (ABS(XI/C1).LT.0.01) GO TO 70
      IF (XI.LT.0.0) GO TO 20
      XIU=XI
      ETAU=ETA
   10 CONTINUE
   20 XIL=XI
      ETAL=ETA
      ETA=0.5*(ETAL+ETAU)
      CY=ETA*CYL
      C1=APP(SLD,CY,CYL,DI)
      IF (NOAPP.NE.0) GO TO 100
      C2=ALL(DI,CY)
      XI=C2-C1
   30 IF (ABS(XI/C1).LT.0.01) GO TO 70
      IF (XIL.LE.XI.AND.XI.LE.XIU) GO TO 40
      GO TO 90
   40 IF (XI.LT.0.0) GO TO 50
      XIU=XI
      ETAU=ETA
      GO TO 60
   50 XIL=XI
      ETAL=ETA
   60 ETA=0.5*(ETAL+ETAU)
      CY=ETA*CYL
      C1=APP(SLD,CY,CYL,DI)
      IF (NOAPP.NE.0) GO TO 100
      C2=ALL(DI,CY)
      XI=C2-C1
      GO TO 30
   70 Y=CY/CYL
      IF (Y.GT.0.455.AND.Y.LT.1.0) GO TO 80
      SCR=((-C(2)-SQRT(C(2)**2-4.*C(3)*(C(1)-ALOG(Y))))/(2.*C(3)))*SLD
      GO TO 110
   80 SCR=(2./PI*ACOS(1.-PI/1.212*(1.-Y)))*SLD
      GO TO 110
   90 WRITE (6,120)
  100 SCR=0.
  110 RETURN
C
  120 FORMAT (30H0ITERATION FAILED TO CONVERGE.)
      END
```

Figure I-14. Source Listing — MININO

```
      SUBROUTINE PANEL
C
      DIMENSION ALPHE(20)
      DIMENSION A(20),ALPHA(99),ALT(99),AX(9,9,9),AY(9,9,9),BETA(99),
     1DIST(9),E(20,99),EAT(20,99),EDOT(20,99),EMIS(9),FCY(20,99),
     2FNET(20),FT(20),FTU(20,99),HINSD(99),MAT(9,9),MPT(9,9),MR(9,18),
     3NI(18),NR(18),PINP(99),Q(9),QCONL(9),QCONT(9),QINP(99),QNET(9),
     4RHO(9),T(20,99),TAMP(9,9),TEMP(9,9),TIME(99),TINSD(99),VFACT(9,18)
     5,VINF(99),X(9),XX(20),Y(9),ZZ(20),TALLW(9)
      COMMON  A       ,AL      ,ALPHA   ,ALT     ,AME     ,AMI     ,AOFA    ,
     1AROD    ,AS      ,AX      ,AY      ,BATA    ,BE      ,BETA    ,BF      ,
     2BFL     ,BL      ,DELTA   ,DIAM    ,DIST    ,DNX     ,DNY     ,DNZ     ,
     3DST     ,E       ,EALL    ,EAT     ,EDOT    ,EMIS    ,FCY     ,FNET    ,
     4FT      ,FTU     ,F07     ,HH      ,HINS    ,HINSD   ,ICONF   ,IQINP   ,
     5ITURB   ,IWALT   ,MAT     ,MPT     ,MR      ,NCOLM   ,NCR     ,NF      ,
     6NI      ,NFSG    ,NR      ,NRSG    ,NSECT   ,NSEG    ,NTRAJ   ,PE      ,
     7PI      ,PINP    ,Q       ,QCONL   ,QCONT   ,QINP    ,QNET    ,R       ,
     8RHO     ,RHOI    ,RYE     ,RYI     ,SL      ,SLS     ,STAAT   ,STI     ,
     9STOOP   ,T       ,TAMP    ,TAU     ,TC      ,TC1     ,TEMP    ,TI      ,
     $TIME    ,TINS    ,TINSD   ,TS      ,UF      ,VFACT   ,VI      ,VINF    ,
     $WROTE   ,X       ,XEMIS   ,XX      ,Y       ,ZZ      ,NCRC    ,TALLW   ,
     $NINS    ,FACC    ,NPRT
C
      GO TO (10,40,70,100,130,160), NSECT
C*****CONFIGURATION NO 1
   10 RHR=(R-HH)/R
      THETA=ACOS(RHR)
      BF=AS-2.*R*SIN(THETA)
      TC1=TC*SIN(THETA)/THETA
      A(1)=.1*(AS-BF)*TS
      XX(1)=.05*(AS-BF)
      ZZ(1)=.5*TS
      DO 20 I=2,5
      A(I)=A(1)
      XX(I)=XX(I-1)+2.*XX(1)
   20 ZZ(I)=ZZ(1)
      A(6)=.25*BF*(TS+TC)
      XX(6)=.5*AS-.375*BF
      ZZ(6)=.5*(TS+TC)
      A(7)=A(6)
      XX(7)=XX(6)+.25*BF
      ZZ(7)=ZZ(6)
      ALPHE(1)=THETA*13./14.
      ALPH=ALPHE(1)
      A(8)=R*THETA*TC1/7.
      XX(8)=R*SIN(ALPH)
      ZZ(8)=R*COS(ALPH)-R+HH+TS
      DO 30 I=9,14
      ALPHE(I-7)=ALPHE(I-8)-THETA/7.
      ALPH=ALPHE(I-7)
      A(I)=A(8)
      XX(I)=R*SIN(ALPH)
   30 ZZ(I)=R*COS(ALPH)-R+HH+TS
      RETURN
C*****CONFIGURATION NO 2
   40 THETA=ATAN(HH/(.5*AS-BF))
      BW=HH/SIN(THETA)
      DX1=.1*(AS-BF)
      A(1)=DX1*TS
      XX(1)=.5*DX1
```

Figure I-15. Source Listing — PANEL

```
      ZZ(1)=.5*TS
      DO 50 I=2,5
      A(I)=A(1)
      XX(I)=XX(I-1)+DX1
   50 ZZ(I)=ZZ(1)
      A(6)=.25*BF*(TS+TC)
      XX(6)=.5*AS-.375*BF
      ZZ(6)=.5*(TS+TC)
      A(7)=A(6)
      XX(7)=XX(6)+.25*BF
      ZZ(7)=ZZ(6)
      DBW=.2*BW
      DXC=DBW*COS(THETA)
      DZC=DBW*SIN(THETA)
      A(8)=DBW*TC
      XX(8)=.5*(AS-BF-DXC)
      ZZ(8)=TS+.5*(TC+DZC)
      DO 60 I=9,12
      A(I)=A(8)
      XX(I)=XX(I-1)-DXC
   60 ZZ(I)=ZZ(I-1)+DZC
      A(13)=.25*BF*TC
      XX(13)=.375*BF
      ZZ(13)=HH+TS+.5*TC
      A(14)=A(13)
      XX(14)=.125*BF
      ZZ(14)=ZZ(13)
      RETURN
C*****CONFIGURATION NO 3
   70 DX=.1*(AS-TC)
      A(1)=DX*TS
      XX(1)=.5*(AS-DX)
      ZZ(1)=.5*TS
      DO 80 I=2,5
      A(I)=A(1)
      XX(I)=XX(I-1)-DX
   80 ZZ(I)=ZZ(1)
      A(6)=.1*HH*TC
      XX(6)=.25*TC
      ZZ(6)=.1*HH
      DO 90 I=7,10
      A(I)=A(6)
      XX(I)=XX(6)
   90 ZZ(I)=ZZ(I-1)+HH/5.
      RETURN
C*****CONFIGURATION NO 4
  100 ABR=.5*(AS-BF)/R
      THETA=ASIN(ABR)
      DZ=R-R*COS(THETA)
      BW=HH-.5*(TS+TC)-DZ
      A(1)=.25*BF*TS
      XX(1)=.5*AS-.125*BF
      ZZ(1)=0.
      A(2)=A(1)
      XX(2)=XX(1)-.25*BF
      ZZ(2)=0.
      ALPH=1.1666*THETA
      A35=R*THETA*TS/3.
      DO 110 I=3,5
      ALPH=ALPH-THETA/3.
```

Figure I-15. Source Listing — PANEL, Contd

```
      A(I)=A35
      XX(I)=R*SIN(ALPH)
  110 ZZ(I)=DZ-(R-R*COS(ALPH))
      A(6)=.125*BW*TC
      XX(6)=.25*TC
      ZZ(6)=DZ+.5*TS+.125*BW
      DO 120 I=7,9
      A(I)=A(6)
      XX(I)=XX(6)
  120 ZZ(I)=ZZ(I-1)+.25*BW
      A(10)=TC*BFL/4.
      XX(10)=.125*BFL
      ZZ(10)=HH
      A(11)=A(10)
      XX(11)=.375*BFL
      ZZ(11)=ZZ(10)
      A(12)=BL*TC
      XX(12)=.5*(BFL-TC)
      ZZ(12)=HH-.5*(TC+BL)
      RETURN
C*****CONFIGURATION NO 5
  130 HR=1.-.5*HH/R
      THETA=ACOS(HR)
      BF=.5*AS-2.*R*SIN(THETA)
      A(1)=.25*BF*TC
      XX(1)=.125*BF
      ZZ(1)=0.
      A(2)=A(1)
      XX(2)=.375*BF
      ZZ(2)=0.
      ALPH1=-0.1*THETA
      A27=.2*R*THETA*TC
      DO 140 I=3,7
      A(I)=A27
      ALPH1=ALPH1+.2*THETA
      XX(I)=.5*BF+R*SIN(ALPH1)
  140 ZZ(I)=R-R*COS(ALPH1)
      DO 150 I=1,7
      J=8-I
      A(I+7)=A(J)
      XX(I+7)=.5*AS-XX(J)
  150 ZZ(I+7)=HH-ZZ(J)
      RETURN
C*****CONFIGURATION NO 6
  160 THETA=ACOS(1.-.5*HH/R)
      AS=2.*(2.*R-HH)*TAN(THETA)
      ALPH1=-0.1*THETA
      A15=.2*R*THETA*TC
      DO 170 I=1,5
      A(I)=A15
      ALPH1=ALPH1+.2*THETA
      XX(I)=R*SIN(ALPH1)
  170 ZZ(I)=R-R*COS(ALPH1)
      DO 180 I=1,5
      J=6-I
      A(I+5)=A15
      XX(I+5)=.5*AS-XX(J)
  180 ZZ(I+5)=HH-ZZ(J)
      RETURN
      END
```

Figure I-15. Source Listing — PANEL, Contd

```
      SUBROUTINE PRA63(ALT,PINF,TINF,RHOINF,ICK)
C
      DIMENSION  PB(14),ZI(5),PK(6,5),RHOK(6,3),TK(6,5),VTK(6,3),
     1ZB(14),TMB(14),LMB(14),DMB(14),MB(14)
      REAL LMB,MB,MWT
      DATA PBASE/6.23101759E-5/
      DATA (ZI(I),I=1,5)/10832.1,17853.3,28000.,49000.,83004./
      DATA (PK(I),I=1,30)          /1.6871582E-2,-1.1425176E-4,-1.3612327
     1E-9,7.3624145E-14,-1.0800315E-17,3.3046432E-22,-7.9910777E-2,-8.10
     246438E-5,-5.5522383E-9,3.1116969E-13,-1.6687827E-17,3.8319351E-22,
     39.8414277E-1,-2.6976917E-4,8.5227541E-9,-3.9620263E-13,1.0146471E-
     417,-1.0264318E-22,
     51.14118495E1,-4.11497477E-4,1.33664855E-8,-3.59518975E-13,
     65.10097254E-18,-2.89055894E-23,
     79.99324461,-2.58298177E-4,3.76139346E-9,-4.20887236E-14,
     81.60182148E-19,-1.92508927E-25/
      DATA (RHOK(I),I=1,18)          /1.3302117E-2,-8.8502064E-5,-4.21430
     156E-9,5.9517557E-13,-3.9744789E-17,7.8771273E-22,1.2667122E-1,
     2-1.3373147E-4,2.0667371E-9,2.3396109E-13,-3.2562503E-17,7.9035209E
     3-22,9.2751266E-1,-1.4349679E-4,-2.8271736E-9,4.7480092E-14,
     41.8863246E-18,-4.2702411E-23/
      DATA (TK(I),I=1,30)          /2.9667877E2,-6.7731001E-3,8.4619805E-
     17,-1.7004049E-10,1.1451454E-14,-2.4898788E-19,
     22.6892151E2,4.3075352E-3,-8.9159672E-7,-2.8929791E-11,5.0724856E-1
     35,-1.1490372E-19,
     43.7064557E2,-3.2858965E-2,2.0645636E-6,-4.3283944E-11,-5.7507242E-
     517,8.2924583E-21,
     62.044798E1,2.07698384E-2,-8.63038789E-7,1.66392417E-11,
     7-9.30076185E-17,-4.09005108E-22,
     8-4.98865953E2,3.92137281E-2,-4.95180601E-7,-3.26219854E-12,
     9 9.66650364E-17,-4.78844279E-22/
      DATA (ZB(I),I=1,14)/
     19.E4,1.E5,1.1E5,1.2E5,1.5E5,1.6E5,1.7E5,1.9E5,2.3E5,3.E5,4.E5,5.E5
     2,6.E5,7.E5/
      DATA (TMB(I),I=1,14)/          180.65,210.65,260.65,360.65,960.65,
     11110.65,1210.65,1350.65,1550.65,1830.65,2160.65,2420.65,2590.65,
     22700.65/
      DATA (LMB(I),I=1,14)/     3.E-3,5.E-3,10.E-3,20.E-3,15.E-3,10.E-3,
     17.E-3,5.E-3,4.E-3,3.3E-3,2.6E-3,1.7E-3,1.1E-3,1.1E-3/
      DATA (MB(I),I=1,14)/  28.9644,28.88,28.56,28.07,26.92,26.66,26.40,
     125.85,24.70,22.66,19.94,17.94,16.84,16.17/
      DATA (DMB(I),I=1,14)/      -0.844E-5,-3.20E-5,-4.9E-5,-3.833E-5,
     12*-2.60E-5,-2.75E-5,-2.875E-5,-2.914E-5,-2.72E-5,-2.0E-5,-1.1E-5,
     2-0.67E-5,-0.67E-5/
      DATA (PB(I),I=1,14)/.172244361E-4,.315971712E-5,.774389807E-6,
     1.265977111E-6,.535849383E-7,.391284945E-7,.295911117E-7,
     2.178715656E-7,.739258171E-8,.200573116E-8,.430456606E-9,
     3.117315480E-9,.370198961E-10,.128115330E-10/
C
   10 Z=ALT*.3048
      IF (Z.GT.700000.) GO TO 160
      IF (Z.LT.0.) GO TO 160
      N=1
      IF (Z-83004.) 20,50,50
   20 IF (Z-ZI(N)) 40,30,30
   30 N=N+1
      GO TO 20
   40 Z2=Z*Z
      Z3=Z2*Z
      Z4=Z2*Z2
```

Figure I-16. Source Listing — PRA63

```
      Z5=Z2*Z3
      GO TO 90
   50 IF (Z-90000.) 130,60,60
   60 IF (Z-ZB(N)) 80,140,70
   70 N=N+1
      GO TO 60
   80 N=N-1
      GO TO 140
   90 TEMPK=TK(1,N)+TK(2,N)*Z+TK(3,N)*Z2+TK(4,N)*Z3+TK(5,N)*Z4+TK(6,N)*Z
     15
      IF (Z-28000.) 100,110,110
  100 PRES=10.0000000*EXP(PK(1,N)+PK(2,N)*Z+PK(3,N)*Z2+PK(4,N)*Z3+PK(5,N
     1)*Z4+PK(6,N)*Z5)
      DENS=(1.16790729)*EXP(RHOK(1,N)+RHOK(2,N)*Z+RHOK(3,N)*Z2+RHOK(4,N)
     1*Z3+RHOK(5,N)*Z4+RHOK(6,N)*Z5)
      GO TO 150
  110 PRES=.000980665*EXP(PK(1,N)+PK(2,N)*Z+PK(3,N)*Z2+PK(4,N)*Z3+PK(5,N
     1)*Z4+PK(6,N)*Z5)
  120 DENS=34.83676*(PRES/TEMPK)
      GO TO 150
  130 TEMPK=180.65
      PRES=PBASE*EXP((-1.373301523E12*(Z-83004.))/(180.65*(6344860.+Z)*(
     16344860.+83004.)))
      GO TO 120
  140 MWT=MB(N)+DMB(N)*(Z-ZB(N))
      TEMPM=TMB(N)+LMB(N)*(Z-ZB(N))
      TEMPK=(MWT/28.9644)*TEMPM
      PRES=EXP(ALOG(PB(N))+(1.373301523E12/(LMB(N)*(6344860.+Z)*(6344860
     1.+ZB(N))))*ALOG(TMB(N)/(TMB(N)+(LMB(N)*(Z-ZB(N))))))
      DENS=34.83676*PRES/TEMPM
  150 PINF=PRES*208.8576
      TINF=TEMPK*1.8
      RHOINF=DENS*0.0019404
      ICK=1
      GO TO 170
  160 ICK=0
  170 CONTINUE
      RETURN
      END
```

Figure I-16. Source Listing — PRA63, Contd

```
      SUBROUTINE PRINT1(ISS)
C
      DIMENSION A(20),ALPHA(99),ALT(99),AX(9,9,9),AY(9,9,9),BETA(99),
     1DIST(9),E(20,99),EAT(20,99),EDOT(20,99),EMIS(9),FCY(20,99),
     2FNET(20),FT(20),FTU(20,99),HINSD(99),MAT(9,9),MPT(9,9),MR(9,18),
     3NI(18),NR(18),PINP(99),Q(9),QCONL(9),QCONT(9),QINP(99),QNET(9),
     4RHO(9),T(20,99),TAMP(9,9),TEMP(9,9),TIME(99),TINSD(99),VFACT(9,18)
     5,VINF(99),X(9),XX(20),Y(9),ZZ(20),TALLW(9)
      COMMON  A       ,AL      ,ALPHA   ,ALT     ,AME     ,AMI     ,AOFA    ,
     1AROD    ,AS      ,AX      ,AY      ,BATA    ,BE      ,BETA    ,BF      ,
     2BFL     ,BL      ,DELTA   ,DIAM    ,DIST    ,DNX     ,DNY     ,DNZ     ,
     3DST     ,E       ,EALL    ,EAT     ,EDOT    ,EMIS    ,FCY     ,FNET    ,
     4FT      ,FTU     ,F07     ,HH      ,HINS    ,HINSD   ,ICONF   ,IQINP   ,
     5ITURB   ,IWALT   ,MAT     ,MPT     ,MR      ,NCOLM   ,NCR     ,NF      ,
     6NI      ,NPSG    ,NR      ,NRSG    ,NSECT   ,NSEG    ,NTRAJ   ,PE      ,
     7PI      ,PINP    ,Q       ,QCONL   ,QCONT   ,QINP    ,QNET    ,R       ,
     8RHO     ,RHOI    ,RYE     ,RYI     ,SL      ,SLS     ,STAAT   ,STI     ,
     9STOOP   ,T       ,TAMP    ,TAU     ,TC      ,TC1     ,TEMP    ,TI      ,
     $TIME    ,TINS    ,TINSD   ,TS      ,UF      ,VFACT   ,VI      ,VINF    ,
     $WROTE   ,X       ,XEMIS   ,XX      ,Y       ,ZZ      ,NCRC    ,TALLW   ,
     $NINS    ,FACC    ,NPRT
C
      N=ISS
      WRITE (6,30) TAU,AL,VI,AOFA,PI,AMI,AME,RYI,PE
      WRITE (6,50) (I,I=1,9),Q,QNET
      DO 10 J=1,NSEG
   10 WRITE (6,60) J,(TEMP(I,J),I=1,9)
      IF (NINS.EQ.1) GO TO 20
      WRITE (6,70) (A(I),XX(I),ZZ(I),T(I,N),FT(I),FNET(I),EDOT(I),FTU(I,
     1N),FCY(I,N),E(I,N),I=1,NPSG)
      WRITE (6,40)
   20 RETURN
   30 FORMAT (1H0,20X3HTAU,10X2HAL,10X2HVI,8X4HAOFA,10X2HPI,9X3HAMI,9X3H
     1AME,9X3HRYI,10X2HPE/12X,9E12.4)
   40 FORMAT (1H1)
   50 FORMAT (//11X1HI,9I12//8X4HQ(I),9E12.4/5X7HQNET(I),9E12.4/)
   60 FORMAT (3X7HTEMP(I,I1,1H),9E12.4)
   70 FORMAT (//11X1HA,10X2HXX,10X2HZZ,11X1HT,10X2HFT,8X4HFNET,8X4HEDOT,
     19X3HFTU,9X3HFCY,11X1HE//(10E12.3))
      END
```

Figure I-17. Source Listing — PRINT1

```
      SUBROUTINE STRESS(ISS,IST)
C
      DIMENSION BMMAX(99),EDO(20),SUME(20)
      DIMENSION A(20),ALPHA(99),ALT(99),AX(9,9,9),AY(9,9,9),BETA(99),
     1DIST(9),E(20,99),EAT(20,99),EDOT(20,99),EMIS(9),FCY(20,99),
     2FNET(20),FT(20),FTU(20,99),HINSD(99),MAT(9,9),MPT(9,9),MR(9,18),
     3NI(18),NR(18),PINP(99),Q(9),QCONL(9),QCONT(9),QINP(99),QNET(9),
     4RHO(9),T(20,99),TAMP(9,9),TEMP(9,9),TIME(99),TINSD(99),VFACT(9,18)
     5,VINF(99),X(9),XX(20),Y(9),ZZ(20),TALLW(9)
      COMMON  A       ,AL      ,ALPHA   ,ALT     ,AME     ,AMI     ,AOFA    ,
     1AROD    ,AS      ,AX      ,AY      ,BATA    ,BE      ,BETA    ,BF      ,
     2BFL     ,BL      ,DELTA   ,DIAM    ,DIST    ,DNX     ,DNY     ,DNZ     ,
     3DST     ,E       ,EALL    ,EAT     ,EDOT    ,EMIS    ,FCY     ,FNET    ,
     4FT      ,FTU     ,F07     ,HH      ,HINS    ,HINSD   ,ICONF   ,IQINP   ,
     5ITURB   ,IWALT   ,MAT     ,MPT     ,MR      ,NCOLM   ,NCR     ,NF      ,
     6NI      ,NPSG    ,NR      ,NRSG    ,NSECT   ,NSEG    ,NTRAJ   ,PE      ,
     7PI      ,PINP    ,Q       ,QCONL   ,QCONT   ,QINP    ,QNET    ,R       ,
     8RHO     ,RHOI    ,RYE     ,RY1     ,SL      ,SLS     ,STAAT   ,STI     ,
     9STOOP   ,T       ,TAMP    ,TAU     ,TC      ,TC1     ,TEMP    ,TI      ,
     $TIME    ,TINS    ,TINSD   ,TS      ,UF      ,VFACT   ,VI      ,VINF    ,
     $WROTE   ,X       ,XEMIS   ,XX      ,Y       ,ZZ      ,NCRC    ,TALLW   ,
     $NINS    ,FACC    ,NPRT
C
      M=1
      KM=1
      ISS=ISS+1
      II=ISS
      J=ISS
      GO TO (10,10,40,70,100,120), NSECT
   10 DO 20 I=1,5
   20 T(I,J)=TEMP(I,1)
      T(6,J)=.5*(TEMP(6,1)+TEMP(6,2))
      T(7,J)=.5*(TEMP(7,1)+TEMP(7,2))
      T(8,J)=TEMP(6,3)
      DO 30 I=9,14
      K=15-I
   30 T(I,J)=TEMP(K,4)
      GO TO 140
   40 DO 50 I=1,5
      K=7-I
   50 T(I,J)=TEMP(K,1)
      XT=5.*TS/HH
      T(6,J)=XT*TEMP(1,1)+(1.-XT)*TEMP(1,2)
      DO 60 I=7,10
      K=I-4
   60 T(I,J)=TEMP(1,K)
      GO TO 140
   70 DO 80 I=1,5
      K=7-I
   80 T(I,J)=TEMP(K,1)
      DO 90 I=6,9
      K=I-4
   90 T(I,J)=TEMP(1,K)
      T(10,J)=TEMP(2,6)
      T(11,J)=TEMP(3,6)
      T(12,J)=TEMP(4,6)
      GO TO 140
  100 DO 110 I=4,14
      K=I-3
      IF (K.GT.9) K=9
```

Figure I-18. Source Listing — STRESS

```
  110 T(I,J)=TEMP(K,1)
      T(1,J)=T(7,J)
      T(2,J)=T(6,J)
      T(3,J)=T(5,J)
      GO TO 140
  120 DO 130 I=3,10
      K=I-2
  130 T(I,J)=TEMP(K,1)
      T(1,J)=T(5,J)
      T(2,J)=T(4,J)
  140 IF (IST.GE.1) GO TO 170
      IST=1
      L=MAT(1,1)
      L=IABS(L)
      CF=FLOAT(NF)*WROTE/7200.
      FCY0=AY(L,5,1)
  150 CALL PANEL
      R1M=0.
      R2M=0.
      R3M=0.
      R4M=0.
      R5M=0.
      R6M=0.
      DMAX=0.
      WBMS=100.
      DO 160 I=1,NPSG
      EDO(I)=0.
  160 SUME(I)=0.
      IF (M.EQ.2.OR.KM.GT.1) GO TO 180
C*****CORRUGATION BM AT MID SPAN
  170 W=PE*AS/144.
      SLP=SLS-2.*BE
      BMMAX(ISS)=W*SLP*SLP/8.
  180 DO 460 N=II,ISS
  190 SUMA=0.
      SUMTA=0.
      SUMMX=0.
      SUMXX=0.
      SUMAZ=0.
      DO 210 I=1,NPSG
      IF (M.EQ.2.OR.KM.GT.1) GO TO 200
      E(I,N)=TRPLAT(AY,AX,T(I,N),L,3,MPT(L,3))
      ALFA=TRPLAT(AY,AX,T(I,N),L,4,MPT(L,4))
      FCY(I,N)=TRPLAT(AY,AX,T(I,N),L,5,MPT(L,5))
      FTU(I,N)=TRPLAT(AY,AX,T(I,N),L,6,MPT(L,6))
      EAT(I,N)=E(I,N)*ALFA*(T(I,N)-530.)
  200 EATA=EAT(I,N)*A(I)
      AE=E(I,N)*A(I)
      SUMA=SUMA+AE
      SUMTA=SUMTA+EATA
      SUMMX=SUMMX+AE*ZZ(I)
      SUMXX=SUMXX+AE*ZZ(I)**2
  210 SUMAZ=SUMAZ+EATA*ZZ(I)
      ABAR=SUMTA/SUMA
      SBAR=SUMAZ/SUMTA
      ZBAR=SUMMX/SUMA
      XXI=2.*(SUMXX-ZBAR*SUMMX)
      XXM=2.*SUMTA*(ZBAR-SBAR)
      XXW=XXM/XXI
      WX=BMMAX(N)/XXI
```

Figure I-18. Source Listing — STRESS, Contd

```
      DFL=(.1042*WX-.125*XXW)*SLS**2
      DMAX1=AMAX1(ABS(DMAX),ABS(DFL))
      IF (ABS(DMAX1).EQ.ABS(DFL)) DMAX=DFL
C*****THERMAL STRESS
      DO 220 I=1,NPSG
      FT(I)=E(I,N)*(ABAR+XXW*(ZBAR-ZZ(I)))-EAT(I,N)
  220 FNET(I)=FT(I)-WX*E(I,N)*(ZBAR-ZZ(I))
C*****STRESS DUE TO APPLIED BM
C*****BUCKLING OF SKIN
      IF (M.EQ.2) GO TO 240
      IF (NSECT.GT.2) GO TO 240
      IF (FNET(1).GE.0.) GO TO 240
      F7=F07*FCY(1,N)/FCY0
      FCR=3.62*E(1,N)*(TS/(AS-BF))**2
      CALL BUCKNG(E(1,N),F7,FCR,FCY(1,N),FTU(1,N),NCR)
      IF (FCR.GE.ABS(FNET(1))) GO TO 240
      DO 230 I=1,4
  230 A(I)=0.
      M=2
      GO TO 190
  240 IF (NSECT.NE.3) GO TO 260
C*****BUCKLING OF LEG SECT NO 3
      BF=AS
      N3=0
      FTT=0.
      DO 250 I=6,NPSG
      IF (FNET(I).GT.0.) GO TO 250
      N3=N3+1
      FTT=FTT+FNET(I)
  250 CONTINUE
      IF (N3.EQ.0) GO TO 260
      BF3=.2*HH*FLOAT(N3)
      FAVE=FTT/FLOAT(N3)
      J=NPSG-N3+1
      F7=F07*FCY(J,N)/FCY0
      FCR=.385*E(J,N)*(TC/BF3)**2
      CALL BUCKNG(E(J,N),F7,FCR,FCY(J,N),FTU(J,N),NCR)
      WB=-FCR/(FAVE*UF)-1.
      GO TO 270
  260 WB=100.
C*****CREEP RATE
  270 WBMS=AMIN1(WBMS,WB)
      DO 460 I=1,NPSG
      IF (A(I).LE.0.) FNET(I)=0.
      FX=FNET(I)
      PLM1=TRPLAT(AY,AX,ABS(FX),L,7,MPT(L,7))
      PLM2=TRPLAT(AY,AX,ABS(FX),L,8,MPT(L,8))
      E1=PLM1/T(I,N)-20.
      E2=PLM2/T(I,N)-20.
      IF (ABS(E1).LT.30.0.AND.ABS(E2).LT.30.0) GO TO 274
      EDOT(I) = 0.0
      GO TO 276
  274 EDOT(I)=ABS(DST/(10.**E2-10.**E1))
C*****STRUCTURAL INDICES FOR THE SELECTION OF CRITICAL TRAJECTORY POINTS
  276 IF (FX.GT.0.) GO TO 280
      R11=0.
      R22=-FX/FCY(I,N)
      R33=R22
      R44=-FX/E(I,N)
      R55=SQRT(R22*R44)
```

Figure I-18. Source Listing — STRESS, Contd

```
      GO TO 290
  280 R11=FX/FTU(I,N)
      R22=FX/FCY(I,N)
      R33=0.
      R44=0.
      R55=0.
  290 R1M=AMAX1(R1M,R11)
      R2M=AMAX1(R2M,R22)
      R3M=AMAX1(R3M,R33)
      IF (R3M.NE.R33) GO TO 300
      I3=I
      N3=N
      FN3=FX
  300 GO TO (310,350,350,320,330,340), NSECT
  310 IF (I.GE.8) GO TO 340
      GO TO 350
  320 IF (I.GE.3.AND.I.LE.5) GO TO 340
      GO TO 350
  330 IF (I.GE.3.AND.I.LE.12) GO TO 340
      GO TO 350
  340 R4M=AMAX1(R4M,R44)
      IF (R4M.NE.R44) GO TO 350
      I4=I
      N4=N
      FN4=FX
  350 GO TO (390,360,390,370,360,390), NSECT
  360 IF (I.GE.13) GO TO 380
      GO TO 390
  370 IF (I.GE.11) GO TO 380
      GO TO 390
  380 R5M=AMAX1(R5M,R55)
      IF (R5M.NE.R55) GO TO 390
      I5=I
      N5=N
      FN5=FX
  390 GO TO (400,400,410,420,420,440), NSECT
  400 IF (I.EQ.6.OR.I.EQ.7) GO TO 430
      GO TO 440
  410 IF (I.LE.5) GO TO 430
      GO TO 440
  420 IF (I.LE.2) GO TO 430
      GO TO 440
  430 R6M=AMAX1(R6M,R55)
      IF (R6M.NE.R55) GO TO 440
      I6=I
      N6=N
      FN6=FX
  440 IF (N.EQ.1) GO TO 450
      SUME(I)=SUME(I)+CF*(EDOT(I)+EDO(I))
  450 EDO(I)=EDOT(I)
  460 CONTINUE
      IF (IST.EQ.2) GO TO 470
      RETURN
C*****ULTIMATE TENSION
  470 T1MS=1./(R1M*UF)-1.
C*****YIELD STRENGTH
      Y2MS=1./R2M-1.
C*****ULTIMATE COMPRESSION
      IF (R3M.LE.0.) GO TO 480
      FCU=AMIN1(1.1*FCY(I3,N3),FTU(I3,N3))
```

Figure I-18. Source Listing — STRESS, Contd

```
      C3MS=-FCU/(FN3*UF)-1.
      GO TO 490
  480 C3MS=100.
C*****BUCKLING OF CORRUGATION
  490 IF (R4M.LE.0.) GO TO 540
      GO TO (500,540,540,510,520,520), NSECT
  500 TX=TC1
      GO TO 530
  510 TX=TS
      GO TO 530
  520 TX=TC
  530 F7=F07*FCY(I4,N4)/FCY0
      FCR=.3*E(I4,N4)*TX/R
      CALL BUCKNG(E(I4,N4),F7,FCR,FCY(I4,N4),FTU(I4,N4),NCR)
      C4MS=-FCR/(FN4*UF)-1.
      GO TO 550
  540 C4MS=100.
C*****CRIPPLING OF FLANGE
  550 IF (R5M.LE.0.) GO TO 580
      GO TO (580,560,580,560,560,580), NSECT
  560 I=I5
      N=N5
      M=1
      TX=TC
  570 FCC=1.385*FCY(I,N)/(SQRT(FCY(I,N)/E(I,N))*BF/TX)**.808
      IF (1.1*FCY(I,N).LT.FCC) FCC=1.1*FCY(I,N)
      IF (FTU(I,N).LT.FCC) FCC=FTU(I,N)
      IF (M.EQ.2) GO TO 640
      F5MS=-FCC/(FN5*UF)-1.
      GO TO 590
  580 F5MS=100.
  590 IF (R6M.LE.0.) GO TO 650
      GO TO (600,600,610,610,620,650), NSECT
  600 TX=TC+TS
      GO TO 630
  610 TX=TS
      GO TO 630
  620 TX=TC
  630 M=2
      I=I6
      N=N6
      GO TO 570
  640 F6MS=-FCC/(FN6*UF)-1.
      GO TO 660
  650 F6MS=100.
C*****TOTAL CREEP STRAIN
  660 EMAX=0.
      DO 670 I=1,NPSG
  670 EMAX=AMAX1(EMAX,SUME(I))
      EMS=AMIN1(T1MS,Y2MS,C3MS,C4MS,F5MS,F6MS,WBMS)
      IF (NPRT.EQ.1) CALL PRINT1(ISS)
      WRITE (6,680) T1MS,Y2MS,C3MS,C4MS,F5MS,F6MS,WBMS,DMAX,EMS,EMAX
  680 FORMAT (//52H0***** S T R E S S   A N A L Y S I S   N O T E *****/
     1/8X4HT1MS,8X4HY2MS,8X4HC3MS,8X4HC4MS,8X4HF5MS,8X4HF6MS,8X4HWBMS,8X
     24HDMAX,9X3HEMS,8X4HEMAX/10E12.4)
C*****SELECTION OF MIN M.S.
      IF (KM.EQ.2) GO TO 700
      IF (EALL.GE.EMAX.AND.EMS.GE.0.) GO TO 750
      KM=2
      DT=.010
```

Figure I-18. Source Listing — STRESS, Contd

```
690 AMAX=EMAX
    AMS=EMS
    TC=TC+DT
    IF (NSECT.EQ.3.OR.NSECT.EQ.4) TS=TS+DT
    II=1
    WRITE (6,770) TC,TS
    WRITE (6,760)
    M=1
    GO TO 150
700 IF (EALL.GE.EMAX.AND.EMS.GE.0.) GO TO 750
    IF (EALL.GE.EMAX) GO TO 710
    DEDT=1.E2*(AMAX-EMAX)
    DT1=(EMAX-.95*EALL)/DEDT
    GO TO 720
710 DT1=0.
720 IF (EMS.GE.0) GO TO 730
    DMDT=1.E2*(EMS-AMS)
    DT2=(.05-EMS)/DMDT
    GO TO 740
730 DT2=0.
740 DT=AMAX1(DT1,DT2)
    KM=3
    GO TO 690
750 WRITE (6,760)
760 FORMAT (34H0***** E N D   O F   N O T E *****)
    RETURN
770 FORMAT (//58H STRESS CONSTRAINTS EXCEEDED - PANEL THICKNESS RESIZE
   1D TO /8H    TC =F6.3,4H IN./8H    TS =F6.3,4H IN./)
    END
```

Figure I-18. Source Listing — STRESS, Contd

```
      FUNCTION TABLE(X,XTB,YTB,N)
C                  THIS SUBROUTINE DOES LINEAR INTERPOLATION,
C                  WHERE Y=F(X).  IT WILL NOT EXTRAPOLATE.
      DIMENSION XTB(1),YTB(1)
C
      I=0
      IF (X.GE.XTB(1).AND.X.LE.XTB(N)) GO TO 10
      WRITE (6,60)
      TABLE=0.
      RETURN
   10 I=I+1
      IF (X.GE.XTB(I)) GO TO 10
      IF (YTB(I-1)-YTB(I)) 20,30,40
   20 Y=(YTB(I)-YTB(I-1))/(XTB(I)-XTB(I-1))*(X-XTB(I-1))+YTB(I-1)
      GO TO 50
   30 Y=YTB(I)
      GO TO 50
   40 Y=(YTB(I-1)-YTB(I))/(XTB(I)-XTB(I-1))*(XTB(I)-X)+YTB(I)
   50 TABLE=Y
      RETURN
C
   60 FORMAT (26H0X ARGUMENT ERROR IN TABLE)
      END
```

Figure I-19. Source Listing — TABLE

```
      SUBROUTINE THERMO(IGO)
C
      DIMENSION D(18),G(10),XM(18),WI(9)
      DIMENSION A(20),ALPHA(99),ALT(99),AX(9,9,9),AY(9,9,9),BETA(99),
     1DIST(9),E(20,99),EAT(20,99),EDOT(20,99),EMIS(9),FCY(20,99),
     2FNET(20),FT(20),FTU(20,99),HINSD(99),MAT(9,9),MPT(9,9),MR(9,18),
     3NI(18),NR(18),PINP(99),Q(9),QCONL(9),QCONT(9),QINP(99),QNET(9),
     4RHO(9),T(20,99),TAMP(9,9),TEMP(9,9),TIME(99),TINSD(99),VFACT(9,18)
     5,VINF(99),X(9),XX(20),Y(9),ZZ(20),TALLW(9)
      COMMON  A       ,AL     ,ALPHA  ,ALT    ,AME    ,AMI    ,AOFA   ,
     1AROD    ,AS     ,AX     ,AY     ,BATA   ,BE     ,BETA   ,BF     ,
     2EFL     ,BL     ,DELTA  ,DIAM   ,DIST   ,DNX    ,DNY    ,DNZ    ,
     3DST     ,E      ,EALL   ,EAT    ,EDOT   ,EMIS   ,FCY    ,FNET   ,
     4FT      ,FTU    ,F07    ,HH     ,HINS   ,HINSD  ,ICONF  ,IQINP  ,
     5ITURB   ,IWALT  ,MAT    ,MPT    ,MR     ,NCOLM  ,NCR    ,NF     ,
     6NI      ,NPSG   ,NR     ,NRSG   ,NSECT  ,NSEG   ,NTRAJ  ,PE     ,
     7PI      ,PINP   ,Q      ,QCONL  ,QCONT  ,QINP   ,QNET   ,R      ,
     8RHO     ,RHOI   ,RYE    ,RYI    ,SL     ,SLS    ,STAAT  ,STI    ,
     9STOOP   ,T      ,TAMP   ,TAU    ,TC     ,TC1    ,TEMP   ,TI     ,
     $TIME    ,TINS   ,TINSD  ,TS     ,UF     ,VFACT  ,VI     ,VINF   ,
     $WROTE   ,X      ,XEMIS  ,XX     ,Y      ,ZZ     ,NCRC   ,TALLW  ,
     $NINS    ,FACC   ,NPRT
      DATA (G(I), I=1,10)/9.2809,-4.734,0.66859,-4.1877E-2,-5.5055E-4,
     12.8367E-4,-2.125E-5,8.0162E-7,-1.5901E-8,1.3236E-10/
      DATA(XM(I),I=1,18)/0.,1.,1.2,1.4,1.6,1.8,2.,2.2,2.4,2.6,2.8,3.,3.4
     1,3.8,4.2,4.6,5.,50./
      DATA(D(I),I=1,18)/14.,6.,10.2,12.3,13.4,13.95,14.,13.8,13.45,12.95
     1,12.4,11.9,10.7,9.65,8.6,7.6,6.6,0./
C
C*****ENTHALPY VISCOSITY AND DENSITY FUNCTIONS
      FENTL(T)=2.2864+0.2272*T+0.11571E-4*T*T+0.23676E-9*T**3
      FMUT(T)=2.27E-8*T**1.5/(T+198.6)
      FMUI1(E)=4.2642E-8*E**.493
      FMUI2(E)=2.8428E-7*E**.228
      FRHO1(P,E)=5.76E-5*P/E**.849
      FRHO2(P,E)=8.65E-6*P/E**.584
C*****FREESTREAM PROPERTIES
      AMI=VI/(49.01*SQRT(TI))
      AM2=AMI*AMI
      VI2=VI**2
      AMUI=FMUT(TI)
      RYI=VI*RHOI/AMUI
      AII=FENTL(TI)
      STI=AII+VI2/50061.5
C*****EFFECTIVE ANGLE OF ATTACK
      ALF=AOFA/57.2957795
      BET=BATA/57.2957795
      CETA=COS(ALF)*COS(BET)*DNX+SIN(BET)*DNY+SIN(ALF)*COS(BET)*DNZ
      AOFA=ASIN(CETA)
      IF (IWALT.EQ.1) GO TO 10
      J=NCOLM
      GO TO 20
   10 J=1
   20 DO 30 I=1,J
   30 WI(I)=FENTL(TEMP(I,1))
      IF (ICONF.EQ.3) GO TO 550
      IF (AOFA.GT.0.612) GO TO 550
      IF (AMI.GT.1.0) GO TO 50
C*****FLAT PLATE
   40 PE=PI
```

Figure I-20. Source Listing — THERMO

```
      VE=VI
      TE=TI
      EI=AII
      AME=AMI
      GO TO 290
   50 IF (AOFA.GE.0) GO TO 120
C*****PRANDTL MEYER EXPANSION
      BETAI=SQRT(AM2-1.0)
      UNI=140.34601*ATAN(.40825*BETAI)-57.29578*ATAN(BETAI)
      IF (AOFA+.05) 60,60,40
   60 UNE=UNI-57.29578*AOFA
      IF (UNE-50.0) 70,70,80
   70 AME=-26.301065/(UNE-81.77828)+.78959002+.02791663*UNE
      GO TO 110
   80 IF (UNE-102.32) 90,90,100
   90 AME=-280.09435/(UNE-130.19996)-.8941241+8.2845071E-03*UNE
      GO TO 110
  100 AME=-284.84684/(UNE-130.43433)-1.0199074+8.6803698E-03*UNE
  110 TR=(5.0+AM2)/(5.0+AME**2)
      PR=TR**3.5
      VR=(AME/AMI)*SQRT(TR)
      PE=PR*PI
      TE=TR*TI
      VE=VR*VI
      EI=FENTL(TE)
      GO TO 290
  120 AMSA=AMI*SIN(AOFA)
      IF (AMSA.LE.0.05) GO TO 40
      AMS2=AMSA**2
      AMS3=AMSA*AMS2
      REFM=VI/1086.0
      RMSA=REFM*SIN(AOFA)
      RMS2=RMSA**2
      RMS3=RMSA*RMS2
      IF (ICONF.EQ.2) GO TO 210
C*****WEDGE
      IF (AMSA.GT.8.0) GO TO 130
      EI=AII*(.9167+.3203*AMSA+.236*AMS2-.4484E-3*AMS3)
      GO TO 140
  130 EI=AII*(1.107-.2209*AMSA+.3644*AMS2-8.462E-3*AMS3)
  140 IF (AMSA.GT.1.8) GO TO 150
      PE=PI*(1.041+.693*AMSA+1.889*AMS2-.0661*AMS3)
      GO TO 160
  150 PE=PI*(-2.32+4.045*AMSA+1.036*AMS2+.0161*AMS3)
  160 IF (RMSA.GE.0.6) GO TO 170
      VR=.1923+1.404*RMSA+1.147*RMS2+.3361*RMS3
      GO TO 190
  170 IF (RMSA.GT.6.0) GO TO 180
      VR=.5958+.4494*RMSA+1.838*RMS2-.0331*RMS3
      GO TO 190
  180 VR=78.03-19.58*RMSA+3.13*RMS2-.05054*RMS3
  190 VE2=VI2-1.0E6*VR
      IF (VE2.GT.0.) GO TO 200
      IGO=1
      RETURN
  200 VE=SQRT(VE2)
      GO TO 280
C*****CONE
  210 IF (AMSA.GT.8.0) GO TO 220
      EI=AII*(1.03+.0827*AMSA+.2354*AMS2-6.956E-4*AMS3)
```

Figure I-20. Source Listing — THERMO, Contd

```
      GO TO 230
  220 EI=AII*(1.106-.3685*AMSA+.3466*AMS2-7.766E-3*AMS3)
  230 IF (AMSA.GE.1.5) GO TO 240
      PE=PI*(1.007+.3816*AMSA+1.522*AMS2-.1593*AMS3)
      GO TO 260
  240 IF (AMSA.GE.5.0) GO TO 250
      PE=PI*(.2397+1.161*AMSA+1.06*AMS2+.0489*AMS3)
      GO TO 260
  250 PE=PI*(-3.182+4.177*AMSA+.8373*AMS2+.0216*AMS3)
  260 IF (RMSA.GE.4.4) GO TO 270
      VR=.157+.75*RMSA+.9861*RMS2+.06944*RMS3
      GO TO 190
  270 VR=6.187-1.038*RMSA+1.414*RMS2-.0062*RMS3
      GO TO 190
  280 TE=17.899+4.0675*EI-.83884E-4*EI**2-.3495E-6*EI**3
  290 IF (EI.GT.705.0) GO TO 300
      EMU=FMUT(TE)
      RHOE=PE/(TE*53.3*32.2)
      GO TO 320
  300 IF (EI.GE.1300.0) GO TO 310
      EMU=FMUI1(EI)
      RHOE=FRHO1(PE,EI)
      GO TO 320
  310 EMU=FMUI2(EI)
      RHOE=FRHO2(PE,EI)
  320 IF (TE.GT.4860.) GO TO 330
      DD=1.432-4.86E-5*TE
      GO TO 340
  330 DD=1.2
  340 AME=VE/SQRT(DD*PE/RHOE)
      PR=0.71
      DO 540 I=1,J
      RYE=RHOE*VE*DIST(I)/EMU
      IF (RYE.GT.1.E6) GO TO 350
      IC=1
      REC=0.84
      GO TO 370
  350 IF (RYE.GT.2.E6) GO TO 360
      IC=2
      REC=0.84
      TFR=RYE/1.E6-1.0
      GO TO 370
  360 IC=3
      REC=0.89
  370 RECI=EI+REC*VE**2/50061.5
C*****ECKERT REFERENCE ENTHALPY
      RI=0.28*EI+0.22*RECI+0.5*WI(I)
      IF (RI.GE.1300.) GO TO 380
      RMU=FMUI1(RI)
      RHOR=FRHO1(PE,RI)
      GO TO 390
  380 RMU=FMUI2(RI)
      RHOR=FRHO2(PE,RI)
  390 RYR=RHOR*VE*DIST(I)/RMU
      IF (IC.NE.2.OR.REC.NE.0.84) GO TO 400
      RYRL=RYR
      RHOL=RHOR
      REC=0.89
      RECIL=RECI
      GO TO 370
```

Figure I-20. Source Listing — THERMO, Contd

```
400 GO TO (410,420,420), IC
410 CF=0.664/SQRT(RYR)
    ST=0.5*CF/PR**(2./3.)*QCONL(I)
    ID=1
    GO TO 440
420 IF (ITURB.EQ.2) GO TO 520
    CF=0.370/(ALOG10(RYR))**2.584
    ST=0.5*CF/PR**(2./3.)*QCONT(I)
430 ID=2
440 IF (IC.NE.2.OR.ID.NE.2) GO TO 450
    HWT=ST*RHOR*VE*32.2
    RYR=RYRL
    RHOR=RHOL
    GO TO 410
450 HW=ST*RHOR*VE*32.2
    IF (IC.NE.2) GO TO 460
    HW=TFR*HWT+(1.0-TFR)*HW
    RECI=TFR*RECI+(1.0-TFR)*RECIL
460 IF (ICONF.NE.2) GO TO 500
    GO TO (470,480,490), IC
470 H=1.73*HW
    GO TO 510
480 H=1.176*HW
    GO TO 510
490 H=(1.73-0.554*TFR)*HW
    GO TO 510
500 H=HW
510 Q(I)=H*(RECI-WI(I))
    GO TO 540
C*****SPALDING-CHI
520 D1=WI(I)/EI
    D2=0.2*REC*AME**2
    D3=1.0+D2-D1
    D4=SQRT(D3**2+4.0*D1*D2)
    D5=ASIN((2.0*D2-D3)/D4)+ASIN(D3/D4)
    FC=(D5/SQRT(D2))**-2
    FR=(RECI/WI(I))**0.772/D1**0.702
    FX=FR/FC
    D6=ALOG(FX*RYE)
    D7=1.0
    D8=0.0
    DO 530 K=2,10
    D7=D6*D7
530 D8=D8+G(K)*D7
    CF=(EXP(D8+G(1)))/FC
    SS=1.+5.*SQRT(FC*CF/2.)*(PR-1.+ALOG((5.*PR+1.)/6.))
    ST=CF*QCONT(I)/(2.*SS)
    RHOR=RHOE
    GO TO 430
540 CONTINUE
    GO TO 710
550 PR=0.71
    AOFS=1.57079-AOFA
    XMI=AMI*COS(AOFS)
    XM2=XMI**2
    XMF=7.*XM2-1.
    IF (ICONF.NE.3.AND.XMF.GT.0) GO TO 570
C*****KEMP-RIDDELL
    H=3.16615E-4*SQRT(RHOI/DIAM)*VI**1.15
    IF (ICONF.EQ.3) GO TO 560
```

Figure I-20. Source Listing — THERMO, Contd

```
      H=0.75*H*(COS(AOFS))**1.2
      IF (AROD.LT.0.0001) GO TO 560
      H=H*SQRT(0.745+3.14*AROD)/1.5215
  560 IS=1
      GO TO 590
C*****BECKWITH-GALLAGHER
  570 FAM=(1.0+.2*AM2)
      FXM=(1.0+.2*XM2)
      PRA=(1.2*XM2)**3.5*(6./XMF)**2.5
      RMU=FMUT(TI*FXM)
      SMU=FMUT(TI*FAM)
      XMU1=RMU/SMU
      XMU2=SMU/AMUI
      VGRD=2./XMI*SQRT(FXM)*SQRT((1.-1./PRA)/0.7)
      ST=0.03231/PR**(2./3.)*(COS(AOFS)*XMU2*VGRD/RYI/DIAM)**0.2*(SIN(AO
     1FS))**0.6*(XMU1*PRA/FXM)**0.8
      REC=0.974+0.051*AOFS-0.213*AOFS**2+0.1*AOFS**3
      H=ST*RHOI*VI*32.174
      IF (AROD.LT.0.0001) GO TO 580
      H=H*((0.745+3.14*AROD)/2.315)**0.2
  580 IS=2
C*****LOCAL PRESSURE AND HEAT FLUX
  590 IF (AMI.LE.1.0) GO TO 670
      TW=TEMP(1,1)
      CBASE=.01132*AMI-.3008/(AMI-.5434)-.05252
      IF (AMI.GE.6.0) CBASE=-1.43/AM2
      DO 600 K=1,18
      IF (AMI.LE.XM(K)) GO TO 610
  600 CONTINUE
      CLOVE=0.
      GO TO 620
  610 CLOVE=(D(K-1)-D(K))*(AMI-XM(K-1))/(XM(K)-XM(K-1))-D(K-1)
      CLOVE=CLOVE/57.29578
  620 IF (TW.LE.0.) GO TO 630
      TWTI=TW/TI
      GO TO 640
  630 TWTI=1.+.17*AM2
      TW=TI*TWTI
  640 CHAP=SQRT(TWTI)*(TI+192.)/(TW+192.)
      CJ=1.721*TWTI+0.132*AM2
      ZD=SQRT(AM2-1.0)
      FACT=SQRT(CHAP)*CJ/(2.*SQRT(RYI))
      Z13=0.734*ZD*ZD/AM2
      DELSTR=.524
      TEMPE=.577*DIST(I)
      IF (TEMPE.LE.FACT) GO TO 650
      DELSTR=ATAN(FACT/DIST(1))
  650 ETA=AOFA+DELSTR
      IF (ETA.GE.1.571) ETA=1.571
      CETA=SIN(ETA)
      IF (CETA.GT.0.) GO TO 660
      CPE=CBASE
      IF (ETA.LE.CLOVE) GO TO 680
      CPE=((1.-.2*ABS(ZD*CETA))**7-1.)/(.7*ZD**2)
      GO TO 680
  660 CPE=CETA*CETA*(Z13+SQRT(1.2+1./(ZD*CETA)**2))
      GO TO 680
  670 CPE=SIN(AOFA)**2
  680 PE=CPE*RHOI*VI**2/64.4+PI
      DO 700 I=1,J
```

Figure I-20. Source Listing — THERMO, Contd

```
      IF (IS.EQ.2) GO TO 690                                            THR 301
      Q(I)=H*(STI-WI(I))*QCONL(I)                                       THR 302
      GO TO 700                                                         THR 303
  690 Q(I)=H*(REC*STI-WI(I))*QCONT(I)                                   THR 304
  700 CONTINUE                                                          THR 305
  710 IF (IWALT.EQ.2) GO TO 730                                         THR 306
      DO 720 I=1,NCOLM                                                  THR 307
  720 Q(I)=Q(1)                                                         THR 308
  730 RETURN                                                            THR 309
      END                                                               THR 310-
```

Figure I-20. Source Listing — THERMO, Contd

```
      FUNCTION TRPLAT (A,B,C,I,J,K)
      DIMENSION A(9,9,9),B(9,9,9)
      IF (C.LE.B(I,J,1)) GO TO 30
      IF (C.GE.B(I,J,K)) GO TO 40
      DO 10 L=1,K
      IF (B(I,J,L)-C) 10,10,20
   10 CONTINUE
   20 TRPLAT=A(I,J,L-1)+(A(I,J,L)-A(I,J,L-1))/(B(I,J,L)-B(I,J,L-1))*(C-B
     1(I,J,L-1))
      RETURN
   30 TRPLAT=A(I,J,1)
      RETURN
   40 TRPLAT=A(I,J,K)
      RETURN
      END
```

Figure I-21. Source Listing – TRPLAT

```
      SUBROUTINE WTTPS
      COMMON/WTA/
     1A      ,B        ,CHORD    ,E1RIB    ,E2RIB    ,E3RIB    ,
     2HBEAMA ,HFNG1    ,HFNG2    ,HRIB     ,HRING    ,IDFNG1   ,
     3IDFNG2 ,KINDP    ,KINDS    ,LENGTH   ,OLPANL   ,LTUBE    ,
     4NRIBS  ,ODPOSR   ,ODPOST   ,ODRING   ,RADIUS   ,TBMLA    ,
     5TBMLC  ,TBMSA    ,TBMSC    ,TCORE    ,TCORN    ,TDOUBC   ,
     6TDOUBP ,TEDGE    ,TFNG1    ,TINS1    ,TINS2    ,TINS3    ,
     7TPLATE ,TPOST    ,T1RIB    ,T2RIB    ,TWRIB    ,TRIBL    ,
     8TRIBS  ,TRING1   ,TRING2   ,TSEAL    ,TSKIN1   ,TSKIN2   ,
     9TTUBE  ,WIDTH    ,WBEAMA   ,WBMLC    ,WBMSC    ,DWPANL   ,
     $WPOST  ,WRIBL    ,WRIBS    ,PBM      ,PCORE    ,PEDGE    ,
     $PINS1  ,PINS2    ,PINS3    ,PPOST    ,PRIB     ,PSEAL    ,
     $PSKIN1 ,PSKIN2   ,PTUBE    ,GBOLT    ,GCLAMP   ,GINSRT   ,
     $GINSUL ,GNUTPL   ,GWASH
      COMMON/WTCOST/
     1KLIC   ,N        ,ACWT     ,KT       ,ITL ,LEN, WID, LTUBER
     2,MAWT,KK,AOP(7,7),KMUV(100,3),KSETUP(100,21),KRUN(100,21)
     3,KCC(5,21),TIME(7),TMAT(3),DIAMA(6),WTNUT(6),TBTABL(6)
     4,KCOSWT(100,3)
      COMMON/ZERO/
     1 TOPWT,TACWT,TMAWT,TTSHR,TTLBHR,TTLACO,TTVCOS,TTFCOS,TTMCOS,
     2TASYCO,LABHR,      LACOST,VCOST,TSTDHR,TLACOS,TVCOST,TFCOST
      COMMON/COMTOT/ CF,K1,STPS,AT,K2,BT,TDH,C,EGTH,NFTA,EFTS,NPA,ETA,
     1EFA,NFLTS,TUNWT
      REAL K1,K2
      REAL KSETUP,KRUN,KCC,MUV,MAWT,KMUV
      REAL KCOSWT
      REAL IDFNG1, IDFNG2, IDRING, LENGTH, LBMLA, LBMLC, LBMSA, LBMSC
      REAL LCORN, LDOUBR, LEN, LPANL, LPOST, LRIBL, LRIBS, LSEAL
      REAL LSTFNR, LTUBE, LTUBER, NXA, NYA
      REAL LARATE,LABHR,LACOST,MFCOS,MATCOS
      J=0
      LEN=LENGTH/12.
      WID=WIDTH/12.
C     INITIALIZE INSULATION VARIABLES
      WTINS1=0
      WTINS2=0
      WTINS3=0
C     INITIALIZE PANEL VARIABLES
      WTCORR=0
      WMCORR=0
      WTEDG2=0
      WMEDG2=0
      WTEDG3=0
      WMEDG3=0
      WTHYCB=0
      WMHYCB=0
      WTRIBS=0
      WMRIBS=0
      WTSKIN=0
      WMSKIN=0
C     INITIALIZE STRUCTURE VARIABLES
      WTBMLA=0
      WMBMLA=0
      WTBMLC=0
      WMBMLC=0
      WTBMSA=0
      WMBMSA=0
      WTBMSC=0
```

Figure I-22. Source Listing — WTTPS

```
      WMBMSC=0
      WTCORN=0
      WMCORN=0
      WTHINA=0
      WMHINA=0
      WTHINB=0
      WMHINB=0
      WTHINC=0
      WMHINC=0
      WTINS=0
      WMINS=0
      WTPOSR=0
      WMPOSR=0
      WTPOSA=0
      WMPOSA=0
      WTPOSB=0
      WMPOSB=0
      WTPOSC=0
      WMPOSC=0
      WTSEAL=0
      WMSEAL=0
      WTFASA=0
      WMFASA=0
      WTFASB=0
      WMFASB=0
      WTFASC=0
      WMFASC=0
C     INITIALIZE TOTAL VARIABLES
      WTINSL=0
      WTPANL=0
      WMPANL=0
      WTSTR=0
      WMSTR=0
C     GENERAL TERMS USED THROUGHOUT
      PI=3.1416
      PI4=.7854
      DIABH1=.19
      DIABH2=.50
      DIAPTH=.50
      DIAPGH=.19
      DIAPOH=.19
      DIARGH=.19
      EEDGE=1.20
      HPLATE=.50
      LDOUBR=2.00
      R=.17
      TBRAZE=.008
      TPLUG=.25
      WDOUBR=1.50
      WDOUBP=1.00
      IF (RADIUS.EQ.0.) CIRCUM=0
      IF (RADIUS.EQ.0.) GO TO 10
      CIRCUM=RADIUS*ACOS(1-(CHORD**2)/(2.*RADIUS**2))
   10 CONTINUE
      HPOST=WPOST
      IDRING=IDFNG2-2.*TTUBE-2.*(IDFNG2-ODPOSR)
      LBMLA=LENGTH-1.75
      LBMLC=LENGTH-.75
      LBMSA=WIDTH-1.75
      LBMSC=WIDTH-.75
```

Figure I-22. Source Listing — WTTPS, Contd

```
      S=R+.365*HBEAMA
      LCORN=2.*HPLATE+2.*S
      LPANL=LENGTH-DLPANL-A
      LPOST=TINS1+TINS2+TINS3+B-.30
      LRIBL=LBMLC
      LRIBS=LBMSC
      LSEAL=WIDTH
      LSTFNR=LPOST-.50
      LTUBER=TINS1+TINS2+TINS3+B
      NXA=(LPANL+DLPANL-4.*DIABH1)/(8.*DIABH1)
      NYA=(LSEAL-4.*DIABH1)/(8.*DIABH1)
      NX=NXA+.5
      NY=NYA+.5
      NXA=NX
      NYA=NY
      ODFNG1=ODPOST+.60
      ODFNG2=IDFNG2+.50
      ODTUBE=ODPOST-2.*TPOST
      TFNG2=TFNG1
      WPANL=WIDTH-DWPANL-A
      WBMLA=2.*(WBEAMA+R-S+((S-R)**2+HBEAMA**2)**.5)+.32
      WBMSA=WBMLA
      WCORN=R+S+((S-R)**2+HBEAMA**2)**.5
      WCORR=WPANL+NRIBS*(CIRCUM-CHORD)
      WPLATE=WBEAMA+2.*R
      WSEAL=A+.5
      WSTFNR=WPOST/3.
      WTBRZ1=LPANL*(NRIBS+1)*.5*TBRAZE*PSKIN2
      WTBRZ2=(LBMLA*.38-2.*NXA*PI4*DIABH1**2)*TBRAZE*PBM
      WTBRZ3=(LDOUBR*WDOUBR-PI4*DIABH1**2)*TBRAZE*PBM
      WTBRZ4=(LBMSA*.38-2.*NYA*PI4*DIABH1**2)*TBRAZE*PBM
      WTBRZ5=(4.*(LCORN*(R+S)-R**2-S**2)+WDOUBP**2-PI4*DIAPGH**2)*TBRAZE
     1*PBM
      WTBRZ6=2.*PI*ODPOST*TPOST*TBRAZE*PPOST
      WTBRZ7=2.*PI*ODPOST*LTUBE*TBRAZE*PPOST
      WTBRZ8=(LPANL+WPANL-EEDGE)*EEDGE*TBRAZE*PEDGE
      WTBRZ9=NRIBS*(LPANL-EEDGE)*(E2RIB+TWRIB)*TBRAZE*PRIB
      IF (E2RIB.EQ.0.) WTBRZ9=0
      WTBR10=2.*WPANL*(EEDGE-TEDGE)*TBRAZE*PEDGE
      WTBR11=4.*(WPOST*HPOST-2.*PI4*DIAPOH**2)*TBRAZE*PPOST
      WTBR12=LBMLC*TRIBL*TBRAZE*PBM
      WTBR13=LBMSC*TRIBS*TBRAZE*PBM
      WTBR14=PI*(ODPOSR-2.*TTUBE)*HRING*TBRAZE*PPOST
      WTBR15=PI*ODPOSR*HFNG2*TBRAZE*PPOST
      WTBR16=PI*ODPOST*TRING1*TBRAZE*PPOST
      WTBR17=PI*ODPOST*HFNG1*TBRAZE*PPOST
      WTBR18=0
      N=0
      ITL=0
C ***
C *** EQUATIONS FOR INSULATION
C ***
C
C *** EQUATION FOR INSUL 1
C
      IF (TINS1.EQ.0) GO TO 20
      WTINS1=LENGTH*WIDTH*TINS1*PINS1/1728.
      IF (TINS2.EQ.0) GO TO 20
C
C *** EQUATION FOR INSUL 2
```

Figure I-22. Source Listing – WTTPS, Contd

```
C
      WTINS2=LENGTH*WIDTH*TINS2*PINS2/1728.
      IF (TINS3.EQ.0) GO TO 20
C
C *** EQUATION FOR INSUL 3
C
      WTINS3=LENGTH*WIDTH*TINS3*PINS3/1728.
C
C *** TOTAL INSULATION WT
C
   20 WTINSL=WTINS1+WTINS2+WTINS3
      ACWT=WTINSL
      MAWT=WTINSL
      KK=97
      KT=1
      N=1
      KLIC=0
      IF (ACWT.GT.0.) CALL COST
      IF (ACWT.GT.0) ITL=1
      ACWT=WTINS1
      MAWT=WTINS1
      KK=91
      KT=1
      N=2
      KLIC=1
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTINS2
      MAWT=WTINS2
      KK=92
      KT=1
      N=3
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTINS3
      MAWT=WTINS3
      KK=93
      KT=1
      N=4
      KLIC=2
      IF (ACWT.GT.0.) CALL COST
      IF ((KINDP.LT.1).OR.(KINDP.GT.4)) GO TO 140
C
C     FORTRAN STATEMENT NUMBER ASSIGNMENTS FOR PANELS
   30 CONTINUE
      GO TO (40,50,60), KINDP
C
C *** TYPE 1 CONSTRUCTION FOR PANELS    ( TYPE 1)
C
   40 CONTINUE
      J=J+1
      GO TO (70,120,130), J
C
C *** TYPE 2 CONSTRUCTION FOR PANELS    (TYPE 2)
C
   50 CONTINUE
      J=J+1
      GO TO (80,100,130), J

C *** TYPE 3 CONSTRUCTION FOR PANELS    (TYPE 3)
C
   60 CONTINUE
```

Figure I-22. Source Listing — WTTPS, Contd

```
      J=J+1
      GO TO (90,110,120,130), J
C ***
C *** EQUATIONS FOR PANELS
C ***
  *** EQUATION FOR CORRUGNS   (CORRUGATIONS)
C
   70 CONTINUE
      WTCORR=LPANL*WCORR*TSKIN2*PSKIN2+WTBRZ1
      WMCORR=(LENGTH+1.)*(WCORR+1.)*(TSKIN2+.005)*PSKIN2
      GO TO 30
C
C *** EQUATION FOR EDGES   (EDGE MEMBERS 2)
C
   80 CONTINUE
      WTEDG2=2.*(LPANL+WPANL+4.*TEDGE-2.*EEDGE)*(TCORE+EEDGE)*TEDGE*PEDG
     1E+WTBRZ8
      WMEDG2=2.*(LPANL+.5+WPANL+.5)*(TCORE+EEDGE+.25)*(TEDGE+.005)*PEDGE
      GO TO 30
C
C *** EQUATION FOR EDGES   (EDGE MEMBERS 3)
C
   90 CONTINUE
      WTEDG3=2.*WPANL*(HRIB+TEDGE+EEDGE)*TEDGE*PEDGE+WTBR10
      WMEDG3=2.*(WPANL+1.)*(HRIB+TEDGE+EEDGE+.25)*(TEDGE+.005)*PEDGE
      GO TO 30
C
C *** EQUATION FOR HONEYCOMB
C
  100 CONTINUE
      IF (KINDS.EQ.1) WTHYCB=LPANL*WPANL*TSKIN2*PSKIN2+(LPANL+DLPANL)*(W
     1PANL+DWPANL)*TSKIN1*PSKIN1+(LPANL-EEDGE)*(WPANL-EEDGE)*TCORE*PCORE
     2-NXA*PI4*DIABH1**2*TSKIN1*PSKIN1+WTBR18
      IF (KINDS.EQ.2) WTHYCB=LPANL*WPANL*TSKIN2*PSKIN2+(LPANL+DLPANL)*(W
     1PANL+DWPANL)*TSKIN1*PSKIN1+(LPANL-EEDGE)*(WPANL-EEDGE)*TCORE*PCORE
     2-4.*PI4*DIAPTH**2*TSKIN1*PSKIN1+WTBR18
      IF (KINDS.EQ.3) WTHYCB=LPANL*WPANL*TSKIN2*PSKIN2+(LPANL+DLPANL)*(W
     1PANL+DWPANL)*TSKIN1*PSKIN1+(LPANL-EEDGE)*(WPANL-EEDGE)*TCORE*PCORE
     2-PI4*DIARGH**2*TSKIN1*PSKIN1+WTBR18
      WMHYCB=LPANL*WPANL*(TCORE+.25)*PCORE+(LPANL+1.)*(WPANL+1.)*(TSKIN2
     1+.005)*PSKIN2+(LPANL+DLPANL+1.)*(WPANL+DWPANL+1.)*(TSKIN1+.005)*PS
     2KIN1
      GO TO 30
C
C *** EQUATION FOR RIBS
C
  110 CONTINUE
      WTRIBS=NRIBS*(LPANL-EEDGE)*(E1RIB*T1RIB+E2RIB*T2RIB+E3RIB*T1RIB+HR
     1IB*TWRIB)*PRIB+WTBRZ9
      WMRIBS=NRIBS*LPANL*(E1RIB*(T1RIB+.005)+E2RIB*(T2RIB+.005)+E3RIB*(T
     11RIB+.005)+(HRIB+.1)*(TWRIB+.005))*PRIB
      GO TO 30
C
C *** EQUATION FOR SKIN
C
  120 CONTINUE
      IF (KINDS.EQ.1) WTSKIN=((LPANL+DLPANL)*(WPANL+DWPANL)-(NXA*PI4*DIA
     1BH1**2))*TSKIN1*PSKIN1
      IF (KINDS.EQ.2) WTSKIN=((LPANL+DLPANL)*(WPANL+DWPANL)-(4.*PI4*DIAP
     1TH**2))*TSKIN1*PSKIN1
```

Figure I-22. Source Listing — WTTPS, Contd

```
      IF (KINDS.EQ.3) WTSKIN=((LPANL+DLPANL)*(WPANL+DWPANL)-(PI4*DIARGH*
     1*2))*TSKIN1*PSKIN1
      WMSKIN=(LENGTH+.1)*(WIDTH+.1)*(TSKIN1+.005)*PSKIN1
      GO TO 30
C
C *** EQUATION FOR TOTAL PANEL
C
  130 CONTINUE
      WTPANL=WTCORR+WTEDG2+WTEDG3+WTHYCB+WTRIBS+WTSKIN
      WMPANL=WMCORR+WMEDG2+WMEDG3+WMHYCB+WMRIBS+WMSKIN
      ACWT=WTPANL
      MAWT=WMPANL
      KK=98
      N=5
      KLIC=0
      IF (ACWT.GT.0.) CALL COST
      IF (ACWT.GT.0) ITL=1
      ACWT=WTCORR
      MAWT=WMCORR
      KK=2
      KT=1
      N=6
      KLIC=1
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTEDG2
      MAWT=WMEDG2
      KK=1
      KT=4
      N=7
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTEDG3
      MAWT=WMEDG3
      KK=1
      KT=2
      N=7
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTHYCB
      MAWT=WMHYCB
      KK=51
      KT=1
      N=8
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTRIBS
      MAWT=WMRIBS
      KK=5
      KT=NRIBS
      N=9
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTSKIN
      MAWT=WMSKIN
      KK=2
      KT=1
      N=10
      KLIC=2
      IF (ACWT.GT.0.) CALL COST
C     FORTRAN STATEMENT NUMBER ASSIGNMENTS FOR STRUCTURE
      J=0
  140 CONTINUE
      IF ((KINDS.LT.1).OR.(KINDS.GT.4)) GO TO 360
      GO TO (150,160,170), KINDS
```

Figure I-22. Source Listing — WTTPS, Contd

```
C
C *** TYPE A CONSTRUCTION FOR STRUCTURE
C
  150 CONTINUE
      J=J+1
      GO TO (180,200,220,230,280,310,320,350), J
C
C *** TYPE B CONSTRUCTION FOR STRUCTURE
C
  160 CONTINUE
      J=J+1
      GO TO (240,260,290,330,350), J
C
C *** TYPE C CONSTRUCTION FOR STRUCTURE
C
  170 CONTINUE
      J=J+1
      GO TO (190,210,250,270,300,340,350), J
C ***
C *** EQUATIONS FOR STRUCTURE
C ***
C
C *** EQUATION FOR BEAM LN A    (LONG BEAM A)
C
  180 CONTINUE
      WTBMLA=(LBMLA*WBMLA-PI4*((2.*NXA+1.)*DIABH1**2+2.*DIABH2**2))*TBML
     1A*PBM+(LDOUBR*WDOUBR-PI4*DIABH1**2)*TDOUBC*PBM+WTBRZ2+WTBRZ3
      WMBMLA=(LBMLA+1.)*(WBMLA+1.)*TBMLA*PBM
      GO TO 140
C
C *** EQUATION FOR BEAM LN C    (LONG BEAM C)
C
  190 CONTINUE
      WTBMLC=LBMLC*WBMLC*TBMLC*PBM+LRIBL*WRIBL*TRIBL*PBM+WTBR12
      WMBMLC=(LBMLC+1.)*(WBMLC+1.)*TBMLC*PBM
      GO TO 140
C
C *** EQUATION FOR BEAM SH A    (SHORT BEAM A)
C
  200 CONTINUE
      WTBMSA=(LBMSA*WBMSA-PI4*2.*NYA*DIABH1**2)*TBMSA*PBM+WTBRZ4
      WMBMSA=(LBMSA+1.)*(WBMSA+1.)*TBMSA*PBM
      GO TO 140
C
C *** EQUATION FOR BEAM SH C    (SHORT BEAM C)
C
  210 CONTINUE
      WTBMSC=LBMSC*WBMSC*TBMSC*PBM+LRIBS*WRIBS*TRIBS*PBM+WTBR13
      WMBMSC=(LBMSC+1.)*(WBMSC+1.)*TBMSC*PBM
      GO TO 140
C
C *** EQUATION FOR CORNERS
C
  220 CONTINUE
      WTCORN=(WDOUBP**2-PI4*DIAPGH**2)*TDOUBP*PBM+(2.*WPLATE**2+8.*WPLAT
     1E*HPLATE-PI4*(DIAPGH**2+DIAPTH**2))*TPLATE*PBM+4.*(LCORN*WCORN-R**
     22-S**2)*TCORN*PBM+WTBRZ5
      WMCORN=(WDOUBP+.25)**2*TDOUBP*PBM+2.*(WPLATE+2.*HPLATE+.5)**2*TPLA
     1TE*PBM+4.*(LCORN+.5)*(WCORN+.25)*TCORN*PBM
      GO TO 140
```

Figure I-22. Source Listing — WTTPS, Contd

```
C
C *** EQUATION FOR INSERTS   (HONEYCOMB INSERTS A)
C
  230 CONTINUE
      IF (KINDP.NE.2) GO TO 140
      WTHINA=NXA*GINSRT/100.
      WMHINA=WTHINA
      GO TO 140
C
C *** EQUATION FOR INSERTS   (HONEYCOMB INSERTS B)
C
  240 CONTINUE
      IF (KINDP.NE.2) GO TO 140
      WTHINB=4.*GINSRT/100.
      WMHINB=WTHINB
      GO TO 140
C
C *** EQUATION FOR INSERTS   (HONEYCOMB INSERTS C)
C
  250 CONTINUE
      IF (KINDP.NE.2) GO TO 140
      WTHINC=GINSRT/100.
      WMHINC=WTHINC
      GO TO 140
C
C *** EQUATION FOR INSULATOR
C
  260 CONTINUE
      WTINS=20.*GINSUL/100.
      WMINS=WTINS
      GO TO 140
C
C *** EQUATION FOR POST CENT   (CENTER POST C)
C
  270 CONTINUE
      WTPOSR=PI*ODPOSR*LTUBER*TTUBE*PPOST+PI4*(ODPOSR-2.*TTUBE)**2*HRING
     1*PPOST-PI4*(IDRING**2*(HRING-TRING2)+DIARGH**2*TRING2)*PPOST+PI4*(
     2IDFNG2**2-ODPOSR**2)*HFNG2*PTUBE+PI4*(ODFNG2**2-IDFNG2**2)*TFNG2*P
     3TUBE+WTBR14+WTBR15
      WMPOSR=PI*ODPOSR*(LTUBER+.5)*(TTUBE+.01)*PPOST+PI4*ODPOSR**2*(HRIN
     1G+.1)*PPOST+PI4*(ODFNG2+.01)**2*(HFNG2+.1)*PTUBE
      GO TO 140
C
C *** EQUATION FOR POST CORN   (CORNER POST A)
C
  280 CONTINUE
      WTPOSA=2.*PI4*(ODPOST**2-ODTUBE**2)*LPOST*PPOST+2.*PI4*(ODPOST**2-
     1DIAPGH**2)*TPLUG*PPOST+2.*PI*ODTUBE*TTUBE*LTUBE*PTUBE+2.*PI4*(ODFN
     2G1**2-ODTUBE**2)*TFNG1*PTUBE+WTBRZ6+WTBRZ7
      WMPOSA=2.*PI4*((ODPOST+.01)**2-ODTUBE**2)*(LPOST+.5)*PPOST+2.*PI4*
     1(ODPOST+.01)**2*(TPLUG+.1)*PPOST+2.*PI4*((ODFNG1+.01)**2-ODPOST**2
     2)*(LTUBE+.1)*PTUBE
      GO TO 140
C
C *** EQUATION FOR POST CORN   (CORNER POST B)
C
  290 CONTINUE
      WTPOSB=4.*((3.*WPOST+2.*LPOST)*HPOST+4.*(LSTFNR-WSTFNR)*WSTFNR-3.*
     1PI4*DIAPOH**2)*TPOST*PPOST+WTBR11
      WMPOSB=(2.*LPOST+3.*WPOST+1.)*(HPOST+1.)*TPOST*PPOST
```

Figure I-22. Source Listing — WTTPS, Contd

```
      GO TO 140
C
C *** EQUATION FOR POST CORN   (CORNER POST C)
C
  300 CONTINUE
      WTPOSC=PI*ODPOST*LPOST*TPOST*PPOST+PI4*(ODRING**2-ODPOST**2)*TRING
     11*PPOST+PI4*(ODPOST**2-DIAPGH**2)*TPLUG*PPOST+PI4*(ODFNG1**2-ODPOS
     2T**2)*TFNG1*PTUBE+PI4*(IDFNG1**2-ODPOST**2)*(HFNG1-TFNG1)*PTUBE+WT
     3BRZ6+WTBR16+WTBR17
      WMPOSC=PI*ODPOST*(LPOST+.5)*(TPOST+.01)*PPOST+PI4*((ODRING+.01)**2
     1-ODPOST**2)*(TRING1+.1)*PPOST+PI4*(ODPOST+.01)**2*(TPLUG+.1)*PPOST
     2+PI4*((ODFNG1+.01)**2-ODPOST**2)*(HFNG1+.1)*PTUBE
      GO TO 140
C
C *** EQUATION FOR SEAL
C
  310 CONTINUE
      WTSEAL=(LSEAL*(WSEAL+.03)-PI4*NYA*DIABH1**2)*TSEAL*PSEAL
      WMSEAL=(LSEAL+1.)*(WSEAL+.5)*TSEAL*PSEAL
      GO TO 140
C
C *** EQUATION FOR FASTNERS   (FASTENERS A)
C
  320 CONTINUE
      WTFASA=(NXA+NYA+2.)*GBOLT/100.+(NXA+2.)*GWASH/100.+(NXA+NYA)*GNUTP
     1L/100.
      WMFASA=1.1*WTFASA
      GO TO 140
C
C *** EQUATION FOR FASTENERS   (FASTENERS B)
C
  330 CONTINUE
      WTFASB=8.*GBOLT/100.+4.*GWASH/100.+8.*GNUTPL/100.
      WMFASB=1.1*WTFASB
      GO TO 140
C
C *** EQUATION FOR FASTENERS   (FASTENERS C)
C
  340 CONTINUE
      WTFASC=2.*GBOLT/100.+GWASH/100.+GNUTPL/100.+GCLAMP/100.
      WMFASC=1.1*WTFASC
      GO TO 140
C
C *** EQUATION FOR TOTAL STRUCTURE
C
  350 CONTINUE
      WTSTR=WTBMLA+WTBMLC+WTBMSA+WTBMSC+WTCORN+WTHINA+WTHINB+WTHINC+WTIN
     1S+WTPOSR+WTPOSA+WTPOSB+WTPOSC+WTSEAL+WTFASA+WTFASB+WTFASC
      WMSTR=WMBMLA+WMBMLC+WMBMSA+WMBMSC+WMCORN+WMHINA+WMHINB+WMHINC+WMIN
     1S+WMPOSR+WMPOSA+WMPOSB+WMPOSC+WMSEAL+WMFASA+WMFASB+WMFASC
      ACWT=WTSTR
      MAWT=WMSTR
      KK=99
      N=11
      KLIC=0
      IF (ACWT.GT.0.) CALL COST
      IF (ACWT.GT.0) ITL=1
      ACWT=WTBMLA
      MAWT=WMBMLA
      KK=3
```

Figure I-22. Source Listing — WTTPS, Contd

```
KT=1
N=12
KLIC=1
IF (ACWT.GT.0.) CALL COST
ACWT=WTBMLC
MAWT=WMBMLC
KK=3
KT=1
N=19
IF (ACWT.GT.0.) CALL COST
ACWT=WTBMSA
MAWT=WMBMSA
KK=3
KT=1
N=13
IF (ACWT.GT.0.) CALL COST
ACWT=WTBMSC
MAWT=WMBMSC
KK=3
KT=1
N=20
IF (ACWT.GT.0.) CALL COST
ACWT=WTCORN
MAWT=WMCORN
KK=4
KT=1
N=14
IF (ACWT.GT.0.) CALL COST
ACWT=WTHINA
MAWT=WMHINA
KK=71
KT=NXA
N=15
IF (ACWT.GT.0.) CALL COST
ACWT=WTHINB
MAWT=WMHINB
KK=71
KT=4
N=15
IF (ACWT.GT.0.) CALL COST
ACWT=WTHINC
MAWT=WMHINC
KK=71
KT=1
N=15
IF (ACWT.GT.0.) CALL COST
ACWT=WTINS
MAWT=WMINS
KK=61
KT=20
N=18
IF (ACWT.GT.0.) CALL COST
ACWT=WTPOSR
MAWT=WMPOSR
KK=11
KT=1
N=21
IF (ACWT.GT.0.) CALL COST
ACWT=WTPOSA
MAWT=WMPOSA
```

Figure I-22. Source Listing — WTTPS, Contd

```
      KK=11
      KT=2
      N=16
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTPOSB
      MAWT=WMPOSB
      KK=5
      KT=4
      N=16
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTPOSC
      MAWT=WMPOSC
      KK=11
      KT=1
      N=16
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTSEAL
      MAWT=WMSEAL
      KK=2
      KT=1
      N=17
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTFASA
      MAWT=WMFASA
      KK=81
      KT=NXA+NYA+2.
      N=22
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTFASB
      MAWT=WMFASB
      KK=81
      KT=8
      N=22
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTFASC
      MAWT=WMFASC
      KK=81
      KT=2
      N=22
      IF (ACWT.GT.0.) CALL COST
  360 KLIC=10
      IF (KINDS.EQ.1) HOLES=NXA+NYA
      IF (KINDS.EQ.2) HOLES=8.
      IF (KINDS.EQ.3) HOLES=2.
      CLAMP=8.
      VOLMAT=HOLES*PI4*DIABH1**2*TSKIN1
      AOP(1,1)=HOLES*TIME(6)
      AOP(2,1)=CLAMP*TIME(1)
      VALUE=VOLMAT*TIME(7)
      IF (VALUE.LE..0011) VALUE=.0011
      AOP(3,1)=HOLES*VALUE
      AOP(4,1)=HOLES*TIME(4)
      AOP(5,1)=HOLES*TIME(2)
      AOP(6,1)=CLAMP*TIME(5)
      AOP(7,1)=HOLES*TIME(3)
      IF (ITL.EQ.0) RETURN
      CALL COST
      RETURN
      END
```

Figure I-22. Source Listing — WTTPS, Contd

APPENDIX II

SUBROUTINE DESCRIPTIONS

PROGRAM TPSOPT is the driver program, which calls the program input routine, increments time in the trajectory, calls for atmospheric conditions, heating rates, temperature computations, the stress analysis, the sonic fatigue analysis, and the determination of weights and costs. The output subroutine is also called from this driver.

FUNCTION ALL computes the slope of the allowable S-N curve of the acoustic fatigue subroutine from the input curve fit coefficients for stress in thousands of psi as a function of the number of stress reversals.

FUNCTION APP determines the slope of an applied sinesoidal S-N curve for an assumed Rayleigh probability distribution - two different fits for various portions of the curve are an integral part of this subroutine.

FUNCTION BANDWIDTH is a table that specifies the octave bandwidth as a function of the center frequency used in the fatigue analysis.

BLOCK DATA is an embedded data table used to determine all material and manufacturing costs of the TPS.

SUBROUTINE BUCKNG iteratively solves for the plasticity correction factor of the thermal stress analysis. In the expression solved, the stress is related to the tangent modulus and modulus of elasticity (the ratio being the plasticity correction factor) in terms of the applied and critical stresses and the Ramberg-Osgood shape parameter.

SUBROUTINE CONDTN explicitly solves the energy equation to predict temperature response of the TPS. Energy terms include both conduction and radiation between nodes. For the latter case, values of the overall interchange factors between nodes must be input to the program. Since the solution is explicit, the possibility of numerical instability exists; nodal temperatures are monitored through the trajectory, and if a temperature changes too rapidly, provision is made to decrease the time step.

SUBROUTINE COST determines the weights of all component parts of the TPS. Material costs, manufacturing standard hours and realization factors, and manufacturing costs are computed here and printed out in the weight/cost summary. Data to compute these numbers are called from the data bank, BLOCK DATA.

SUBROUTINE COSTOT determines the total program cost to develop, manufacture, and test 22,000 square feet of the TPS. These costs, based on historical data, the weight of the TPS, and the complexity factor for the material/configuration predict total program costs for the theoretical first unit, non-recurring costs, engineering design and development, tooling ground and flight test hardware, spares, recurring production and operations, and refurbishment.

FUNCTION CURVEF computes the decrease of the octave band sound pressure level (OBSPL) from the maximum value ($OBSPL_{max}$) as a function of the number of octaves difference between the frequency f' of $OBSPL_{max}$ given by $f'D/U = 0.8$ and the fundamental frequency of the panel. The falloff is either 4 or 3.5 db/octave depending on whether the natural frequency f is above or below the characteristic frequency f'. All calculations supplement the sonic fatigue analysis.

SUBROUTINE DRVTPS is the driver subroutine for the weights/cost analysis. Input to this analysis is read by DRVTPS instead of the major input subroutine INPUT1, and the input data are printed out by DRVTPS. All constants used in either the weight or cost analysis are initialized here. The weight and manufacturing cost subroutines are called through subroutine WTTPS from this point in the program, and the total program cost subroutine COSTOT is also called here.

SUBROUTINE FATIG performs all sonic fatigue analysis of the program except input of its own data. This is passed from the subroutine INPUT1 through the name common block SONIC1. Sound pressure levels are predicted at this point in the subroutine from any or all of the four sources considered, and the panel fundamental frequency is determined for the panel under consideration. Root mean square and peak dynamic stresses as well as the expected number of stress reversals for each noise source are determined, and the resulting S-N data derived from a Rayleigh probability function are compared to allowable S-N data which have been input to the program. Results of the analysis are printed out by FATIG.

SUBROUTINE INPUT1 reads and prints out all input data except those used in the weights/cost analysis. Panel geometrical parameters, material properties, the trajectory, and radiation interchange factors as well as indices which specify options to be performed by the program are read and then written out for the program user.

SUBROUTINE MININO performs the iteration to compute the critical stress of the sonic fatigue analysis. This is performed mathematically by determining the stress at which the applied and allowable S-N curves are tangent. The slopes of these curves are obtained by calling subroutine APP and ALL, respectively.

SUBROUTINE PANEL computes geometric properties of the discrete elements for the thermal stress analysis from the general panel dimensions which have been input to the program.

SUBROUTINE PRA63 calculates freestream atmospheric properties of temperature, pressure, and density as a function of altitude using curve fits of properties of the 1963 Patrick Reference Atmosphere.

SUBROUTINE PRINT1 is the main output subroutine which writes out aerothermodynamic characteristics of the environment such as fluidynamic properties and vehicle attitude as well as temperature and stress distributions of the panel cross-section.

SUBROUTINE STRESS performs the discrete element thermal stress analysis on each of the six panel configurations depending upon which is under consideration. At increments in the trajectory equal to the print interval, nodal temperatures are interpolated from the temperature distribution, and thermal stresses are determined along with design factors and creep rates. All these values are stored in arrays for use at the end of the trajectory at which time the minimum design factors are identified. If any are negative, the panel thickness is increased and stresses recomputed. The panel thickness is increased until all design factors are positive.

FUNCTION TABLE is a linear interpolation subroutine used for a number of table look-ups throughout the program.

SUBROUTINE THERMO is the procedure whereby local flow properties are computed from freestream values using either oblique or conical real gas shock relations for low angles of attack or swept cylinder methods for high angles. Heating rates are computed using either Eckert or Spalding-Chi heating prediction techniques for attached shock wave flows or either Fay-Riddell or Beckwith-Gallagher swept cylinder methods for high angles.

FUNCTION TRPLATE is a specialized linear interpolation routine for a triply subscripted variable used for determining material properties in the stress analysis.

SUBROUTINE WTTPS computes the weights of all component parts of the TPS panel insulation and supporting structure. Manufacturing costs are computed by calling subroutine COST.

APPENDIX III

PROGRAM FLOW CHART

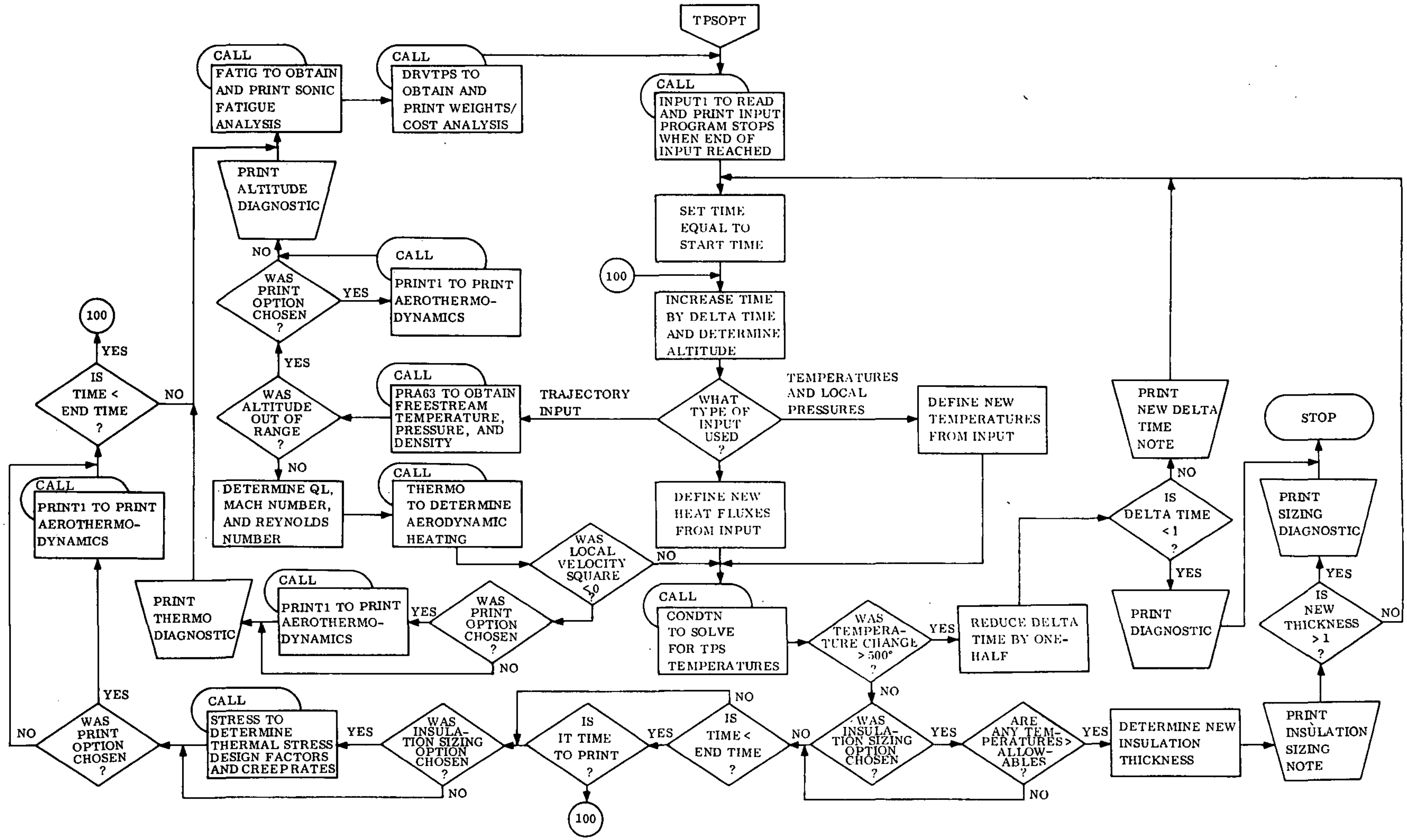

Figure III-1. Program Flow Chart

GENERAL DYNAMICS

Convair Aerospace Division